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FIRE IN TROPICAL FORESTS AND GRASSLANDS

by

Robert B. Batchelder, Ph.D.

and

Howard F. Hirt, Ph.D.

Boston University

Boston, Massachusetts

Contract No. DA19-129-AMC-229(N)

June 1966

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U.S. Army Materiel Command
U.S. ARMY NATICK LABORATORIES
Natick, Massachusetts

FOREWORD

Centuries of clearing and burning in tropical forests and grasslands have produced profound changes in physical and cultural environments. The frequent and widespread occurrence of fire poses a major hazard to the successful operation of men and equipment. Accordingly, there is need for information of a comprehensive and detailed character on the myriad aspects of fire in the tropics. This report contributes to the fulfillment of the U.S. Army's requirements for knowledge of world physical and cultural environments. Prepared in two sections, text and classified bibliography, this report is an evaluation of a vast and diverse literature. Emphasis is on the frequency, season of occurrence and geographic distribution of fire. Wherever possible, the interrelations between fire and the total environment, its possible influence on military operations and practices and methods for controlling fire have been stressed. The study, begun in February 1964 (Project No. 1V025001A129) was conducted in the Department of Geography, Boston University, under contract No. DA-19-129-AMC-229(N) over a period of nearly two and one-half years.

Dr. Robert B. Batchelder directed the project as Principal Investigator, assisted by Dr. Howard F. Hirt as Research Associate. Dr. George K. Lewis assisted as consultant on African material. Messrs. Roberts Mednis and Robert Easton assisted in library research and compilation of bibliography. Mr. Mednis directed the cartographic work, assisted by Mr. John George and Mrs. Uttara Bose. Mrs. Lillian Funk typed the drafts and final copy; proof reading and editorial assistance was provided by Mrs. Ruth Batchelder; bibliographical assistance by Miss Linda Morrissey.

Robert B. Batchelder
Boston University
June 1966

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ABSTRACT

Fire in the tropics has a long history in which frequent widespread burning has profoundly altered physical and cultural environments. A vast and diverse literature pertaining to fire and its effects in tropical forests and grasslands has been evaluated, classified and presented in a selected bibliography. Fire behavior in the field is at present unpredictable. In this report, the numerous variables interacting with fire are analyzed. Emphasis is on the relation of fire to climate, natural vegetation, soils, cultural origins, technological level and way of life and other significant factors of the total environment. The incidence and frequency of occurrence of fire are examined in terms of the geographic distribution of passive and active environmental characteristics. The relationship of burning to climate and natural vegetation is shown on maps which represent a first attempt to depict the geographic distribution of fire in the tropics. Potential combustibility and the implications of fire to military operations are discussed.

CHAPTER I

FIRE IN THE TROPICS

A. Introduction

Fire has a long history of occurrence in the tropical world, and its effects upon the physical and cultural environment have been profound. The causes of fires and the trends in use by various peoples, however, have changed greatly within historic times. Prior to the advent of use of fire by man, the effects of natural fire are assumed to have been much more limited than natural fire today. It is reasoned that the geographic distribution of humid tropical forests was much wider during the early Pleistocene than at present. In the forest microclimate combustibility would have been low, limiting the period in which fire, once ignited, could be sustained. As a result, the geographic area subject to possible widespread fires is presumed to have been limited to areas climatically transitional from moist to semiarid Pleistocene climates. A general assumption is that natural fires were caused principally by lightning and volcanic activity, of which the latter must have been of more importance in regions clothed with humid forests.

The advent of man's use of fire is of great importance because a new cycle was introduced, marked by cultural practices fostering widespread distribution of fire and an increased frequency of occurrence. Various lines of evidence suggest that the control of fire by man may not be more than 12,000 years old, even though, as noted by Stewart (1956), man may have guarded and transported fire for thousands of years earlier. Authorities believe

that no evidence suggests that man in Africa knew how to make or use fire before the end of the Early Stone Age. One of the earliest records of fire, noted by Busse (1908), was by Hanno, the Carthaginian, who sailed along the West Coast of Africa circa 500 B C , and noted the burning of vegetation. Palynological data for the Llanos Orientales of Colombia and the Rupununi Savanas of Guyana (British Guiana) suggest that human influence was probably an important factor 3,000 years B.P. (Wymstra and van der Hammen 1965)

More recently, fire has been used widely throughout the tropics to drive game, collect honey, ease travel through densely vegetated areas, provide new succulent forage for grazing animals, clear land for cultivation, and make war on neighboring peoples. Use of fire is so deeply ingrained in certain cultures, that it has become an essential part of religious beliefs and taboos. Numerous authors also suggest that pyromania is widespread in which fires are set but the reasons for doing so, in many cases, are long since forgotten by the people.

That certain parts of the tropics are experiencing more extensive and intensive alteration of the natural landscape by fire is well documented. Use of fire and its effects appear to have declined in Oceania and parts of South and Southeast Asia, notably India. The agricultural populations have become sedentary, while primitive cultivators using fire in clearing forest represent an unimportant minority located in remote geographic areas. On the other hand, cultural use of fire is increasing in much of Africa and parts of tropical and subtropical Latin America. The rate of population increase is high particularly among rural people. Consequently, new lands are being sought for clearing by expanding populations. In already settled areas, population increase has disastrously shortened the period of forest fallow among shifting cultivators.

Although no one generalization can be applied to the entire tropics, it is clear that the effects of fire on the natural and cultural environment are increasing at an increasing rate. Numerous scholars and administrators, noting the change accompanying widespread use of fire, have appealed for more intensive and wider study

B. Scope and Purpose of Study

1. Scope of the Literature

For more than two centuries, observers and investigators have reported on the history of burning of vegetation in the tropics. Much of the literature reflects both concern for and interest in the long-range effect of burning, the objectives of those who burn as a part of a way of life, and the effects of fire upon plants, soils, animals and other phenomena. During this period the character of references has varied. Early works frequently are narrative accounts written by missionaries, explorers, and administrators traveling in little-known areas. These accounts are of inestimable value, particularly for establishing the historical evolution of the natural and cultural landscapes in relation to the effects of fire. Contemporary research on fire is vast, representing a wide spectrum of academic disciplines as well as private and government agencies, personnel and laboratories. Intensive research extends from laboratory experimentation on behavior of fire under controlled conditions, to field studies on fire behavior under natural conditions in which the large number of variables are instrumentally measured. Numerous intensive studies also have been conducted in small areas, and include analyses of environmental and cultural milieus of tribal peoples, ecological vegetation studies, experimentation on fires' effects on soils, plant succession in relation to time of burning, best burning policies in relation to commercial range and forest management and many others.

Furthermore, ideas and attitudes towards fire and its effects in the tropical environment, as expressed in the literature, have in many instances changed significantly. For example, references dated prior to the early 20th century frequently contain alarming predictions of soil deterioration and erosion, loss of vegetative cover and destruction of landscape. No doubt exists that widespread destruction of forests has occurred in parts of the tropics. However, other effects and predictions have not been verified for all locations for which predictions were made. Early literature often reflected essentially the authors' experience with fire in temperate latitudes, which largely demanded total fire prevention for preservation of the existing environment. More recent studies recognize fire as an indispensable tool in the agricultural economy, and in forest and range management in most tropical areas. Nearly all authorities agree that widespread, indiscriminate, uncontrolled burning is disastrous but that fire properly used is an effective low-cost measure, and the only economical means by which certain tropical environments can be managed for maximum resource use.

2. Purpose of the Study

The number of ramifications of the role played by fire is nearly infinite penetrating all aspects of the tropical environment. Recognizing a need for a preliminary study of fire in the tropics, a necessary precursor to subsequent investigation, the U. S. Army Natick Laboratories sponsored a search of the literature, to include sources in all major languages, to be conducted over a period of two years. Particular stress was to be laid on ascertaining the influence of the physical and cultural environment in tropical forests and grasslands on the occurrence and frequency of fire, as well as the effect of fire upon the natural and

cultural environment. Significant contributions found in the literature were extracted for incorporation in this report.

In this study, fire is considered to be a phenomenon operating under physical laws and processes and acting as a physical agent in modifying the physical and cultural environment. In turn, fire-altered landscapes are presumed to trend toward conditions favorable for an increasing occurrence and frequency of fire. Because the number of possible interrelationships among fire, man, and environment are nearly infinite, no one condition or set of conditions can be assumed to be dominant for all parts of the tropics. Consequently, many researchers support an ecological or holistic view, in which fire is only one component of the total environment. Although the immediate effects of fire are easily perceived and are frequently catastrophic, there are, according to this view, no valid reasons for ascribing to fire a role uniquely different or in some way "separate" from the environment. Recognizing the emotional aspects of fire, Reifsnyder (1965) commented at the Tenth Pacific Science Congress, University of Hawaii, August, 1961:

Deep-rooted psychological attitudes towards fire have ... distorted man's approach to the use of fire in wild-land management. Traditions for or against use of fire have often prevented rational research on effects and use of fire. Of particular importance ... is the role of fire in agricultural practices in the tropics and subtropics. There is perhaps no other subject in fire so circumscribed with emotional bias as the use of fire in shifting agriculture. Much more objective research is needed in this important area.

Currently the most widespread and accepted view on fire is an ecological one, and such a view is supported in this study.

This report is divided into two sections, text and classified bibliography. For several reasons, the bibliography assumes a more important role than it might

otherwise and should be considered of value equal to that of the text. The text stresses the following: 1) fire as a natural phenomenon, particularly its characteristics and behavior under natural environmental conditions; 2) the interaction of fire with the physical environment, notably climate, aperiodic patterns of weather, natural vegetation, soils, and other aspects of the environment; 3) the interaction of fire with the cultural environment, particularly those cultural aspects determining the use of fire, selection of sites for burning, techniques employed in burning, and time of burning as determined by agricultural calendars, religious or other beliefs; and 4) the geographic distribution of the occurrence of fire and probable period of burning correlated to climatically determined ecologically dry months and natural vegetation. In various sections of the total report, aspects of the total environment which are due to fire's effect on living conditions and mobility of people have been noted.

The bibliography is arranged in two separate sections and organized for maximum flexibility in its use. References contained in the first section are grouped according to large sections of the various continental areas, such as Western Africa, Southeast Asia, and Middle America, and arranged alphabetically by author under each section. Each reference is further identified according to its contents by a code system which indicates the various topics covered in the reference. The code also identifies the country or countries either in which the study was conducted or to which the study refers. The second section of the bibliography is classified as is the first section, and contains references known to be valuable to study of fire in the tropics. However, the references are not classified topically according to contents since they represent the later additions to the general bibliography which was kept current up to the preparation of this report.

Preview of existing bibliographies preceded establishing the criteria to be employed in selecting references for inclusion in the bibliography accompanying the text. The three-volume annotated bibliography, compiled by the late H.H. Bartlett (1955, 1957, 1961), and the selected bibliography compiled by H. C. Conklin (1963), containing more than 1,300 references pertaining to shifting cultivation in the tropics, were evaluated.¹ There appeared to be no valid reason for repeating the excellent work accomplished by these men. Certain significant references making substantial contributions to the literature pertaining to fire and appearing in the bibliographies mentioned above, are reproduced in the bibliography accompanying this report. Wherever possible, however, duplication was avoided.

Readily available general works and textbooks were not included in the bibliography. Similarly, references which by their titles appeared promising but contained only brief and casual reference to fire were omitted. In addition, relatively few references were included that were dated before 1920. It was quickly established that earlier signif-

¹The following sources contain references to research on fire in the tropics but references to fire in extra-tropical areas are more numerous:

Berl, Walter G. (ed.) Fire Research Abstract and Reviews.
National Acad. of Sci.-National Res. Coun. Wash., D.C.

This publication, printed three times annually, contains abstracts of papers published in scientific journals, progress reports of sponsored research, and reports of technical laboratories.

References to Scientific Literature on Fire, Dept. of Scientific and Indust. Res. and Fire Officer's Committee Joint Fire Res. Organ., Forest Res. Sta., Boreham Wood, Hertfordshire, England.

An annual mimeographed publication listing all published materials appearing that year and topically arranged under subheadings, such as, occurrence of fire, ignition and combustion studies, fire precaution, fire resistance, fire fighting organization and general works.

icant references were invariably cited in full in more contemporary literature. Exceptions were made for references to fire in geographic locations for which information was scanty. No other restrictions, either geographical or topical were intended; however, gaps undoubtedly exist. References to works in non-European languages are few. Every effort has been made to produce a bibliography representing the wide diversity of fields of interest as revealed by the vast literature.

C. Delimiting the Tropics

Initially, the tropics were to be determined solely by climatic criteria. A first approximation was made by limiting the tropics to the Af (tropical rainy), Am (tropical monsoon), and Aw (tropical wet-and-dry) types of climate as determined by the Koeppen Classification. Comparisons were made of the areas thus delimited with the geographic distribution of climates determined by other classification systems and with major formations of natural vegetation (Chambers, Dalrymple and Jones, 1957). It was concluded that climatic criteria were too restrictive because fire was also significant in areas experiencing semiarid climates and cool highland climates. Fire is important in all types of natural vegetation where fuel quantities and spacing are sufficient to sustain combustion.

In many parts of the tropics, similarities were noted in the time of burning regardless of whether it occurred in lowlands or uplands. Conversely, numerous sharp differences were discovered in which the period of burning was closely related to cultural practices regardless of similarity of the physical environment. For these reasons, the investigation was extended to all land located between the Tropics of Cancer and Capricorn, and including South Africa and parts of subtropical Australia. In order to present the comprehensive role and effects of fire, a

diffuse delimitation of the tropics was found to be more realistic.

D. Sources and Methods Used in Study

Most of the information used in the preparation of this report was obtained from libraries in the United States. Significant references in unobtainable foreign journals invariably appeared in full in one or more other available publications. Visits were made to a number of libraries containing collections pertinent to the study.

A valuable supplement to the literature survey was an extensive correspondence with potential informants. Letters of inquiry were sent to individual scholars, university departments, government agencies, independent research centers and international business firms. The response from those best able to assist the study was excellent. The information thus acquired proved invaluable, particularly in terms of the insight and observations of persons and agencies who became known to us during their visits to the eastern portion of the United States.

Information extracted from all sources was recorded in triplicate and organized separately in a regional file, a topical file and a chronological file. Items in the regional file were organized by continental area and country. The contents of a given reference were classified topically by a code system and filed under the headings in the topical file. The chronological file contained copies of all references organized in numerical order, the number being assigned at the time the material was extracted. The latter file was indispensable for cross-checking reference entries to avoid duplicating work, especially those references appearing in more than one publication. Bibliography cards were made for each reference with a notation of its form number and the geographic location number. Retrieval of information recorded

on some one thousand forms was greatly facilitated by this system. Not only could all topics on fire for a country be quickly assembled, but also the ease with which one could extract material on a single topic for the entire topical world exceeded expectations.

REFERENCES CITED

- Bartlett, H. H. (1955, 1957, 1961) Fire in relation to primitive agriculture and grazing in the tropics, University of Michigan, Ann Arbor, Michigan, Vol. I. 568 p.; Vol. II, 873 p.; Vol. III. 216 p.
- Busse, Walter (1908) Die periodische Grasbrände im tropischen Afrika, ihr Einfluss auf die Vegetation und ihre Bedeutung für die Landeskultur, Mitteilungen aus den deutschen Schutzgebieten. Vol 20, No. 2:113-139.
- Chambers, Dalrymple and Jones (1957) Wet tropics: limits and characteristics. Technical Report EP-63, Quartermaster Research and Engineering Center. Natick, Mass. 26 p.
- Donklyn, H. C (1963) The study of shifting cultivation, Pan American Union, Washington, D. C., 185 p.
- Reifsnyder, W. E (1965) Symposium on forest fire research at Tenth Pacific Science Congress - University of Hawaii, August 31, 1961, Fire Res Abstr and Rev. 7(2):73-75.
- Stewart, O. C. (1956) Fire as the first great force employed by man in: Thomas, W. L. Jr., Man's Role in Changing the Face of the Earth, Chicago. Univ of Chicago Press, pp. 115-133
- Wijmstra, T. A. and T. van der Hammen (1965) Palynological data on the history of tropical savannas in northern South America. 30 p (in press)

Chapter II

FIRE BEHAVIOR AND CHARACTERISTICS

A. Introduction

Present knowledge concerning the characteristics and behavior of fire is largely empirically derived from observations as man has combatted uncontrolled fires or has successfully used fire as a tool. Many of the characteristics of flame ignition, fire propagation and fire persistence are recognized only in qualitative terms, often without complete understanding of the processes involved. At the present time, it is impossible to predict the behavior and course of a fire. While many factors such as wind, humidity, fuel type, and topography are recognized as important, no quantitative estimates can be made of flame height, the magnitude and direction of fire-induced wind velocity, the radiative energy loss and its effect on convection, and the drying and gasification of the fuel. Inability to predict these characteristics renders difficult, if not impossible, meaningful prediction of behavior of the firefront and the persistence and spread of fire. The following qualitative description of a forest fire illustrates the complexity of fire and the number of interrelating factors involved in its behavior.

"A forest fire has burned for some hours. There is a growing perimeter of active combustion. Flames and smoke cover the luminous solid remains of grass, brush, and trees. Radiation from the luminous flames heats the fuel in and ahead of the fire front. The amount of heat thus received, together with convected heat by the rising convection column.

gasifies additional fuel. The non-uniform fuel distribution and details of the topography cause convection columns and flames which are here violent, there gentle. By interaction with the general wind, these irregular columns help produce eddies, small whirlpools of gases and firebrands which help propagate the fire front. The rising convection column alters the local wind pattern and thus alters the manner in which air is brought into the fire for its maintenance and the manner in which hot gases and brands are moved for its spread."¹

B. Behavior of Fire

1 Ignition and Sustained Combustion

For combustion to occur, the temperature of the fuel must reach a value, or threshold, where volatile gases are emitted from the fuel which upon reacting with the oxygen of the air ignite. Solids and liquids do not burn directly, but rather the gases emitted from these fuels at various temperatures burn. Organic compounds making up wood and grass, resins and oils, have a wide range of boiling points. Water also is present in varying amounts, both as a liquid and as chemisorbed water vapor. When a fuel is exposed to heat, it warms to where the water vapor boils off and in that process steam distillation probably takes place, whereby organic chemicals with a boiling range similar to water vapor are carried along with the steam. Continued heating after removal of the water vapor results in volatilization of additional organic compounds, which upon reaction with oxygen of the air, burst into flame, and a self-sustaining combustion process is established.

Once the fuel reaches a stage of sustained combustion, the flame propagates by having the heat generated by the initial combustion process transferred to adjacent unignited fuel by convective and radiative heat transfer.

¹A Proposed Fire Research Program. The Committee on Fire Research and The Fire Research Conference. Nat Acad. of Sci. Wash., D C. 1959. n.p.

If the above explanation is at all adequate, it becomes clear that ignition, persistence of continuous combustion, and propagation of fire largely depends on the type, quantity and moisture content of the fuel or fuels, and that the areal arrangement of the fuels is very important during the initial phase of development of a fire front.

Controlled experiments in burning grasslands and forests in the tropics reveal that relatively high ignition temperatures characterize many, if not most fuels, and that combustion is not as easily sustained as the parched appearance of a landscape during the dry season would suggest.

Vareschi (1962) conducted a number of burnings in the Sabana de Calabozo, Venezuela, in which the typical vegetative formation was savanna parkland. Pyranometers were used to measure temperatures at various levels during burnings, and the same instruments were used to determine ignition temperatures of Trachypogon montufari, the dominant grass, and of other grasses and trees. The marked increase in ignition temperature of the Trachypogon m., when the fuel is not completely cured, is evident from Table 1.

TABLE 1

IGNITION TEMPERATURES OF SELECTED GRASSES
Sabana de Calabozo, Venezuela

Grasses	Fuel condition	Month	Wind	Ignition Temp.	
Trachypogon montufari	dry stage	Feb.	no wind	129°C	(264°F)
Trachypogon montufari	dry stage	Feb.	wind 3 m/sec.	135°C	(275°F)
Trachypogon montufari	almost dry stage	Dec.	no wind	205°C	(401°F)
Axonopus (and other grasses)	dry stage	Feb.	no wind	130° to 160°	(266°F to 320°F)

Ignition temperatures of the wood and bark of the Chaparro (Curatella) and Chaparro Marleca (Byrosonima) in a dry state ranged from 290°C to 330°C (554°F to 626°F). On the other hand the ignition temperature of the same species climbed to 500°C (932°F) or more, if the bark contained sap. Considering the fuel types and arrangement typical of the vegetative formations of the Sabana de Calabozo, Vareschi concluded that marked dessication of vegetation must precede uncontrolled fire.

The variation of average ignition conditions of the savanna in the Calabozo area is compared against the distribution of monthly rainfall at Bancos de San Pedro (Fig. 1). Low ignition temperatures coincide with the end of the dry season and the danger of unmanageable fire begins in January. It also is apparent that from May to December, the savanna is almost impossible to set afire.

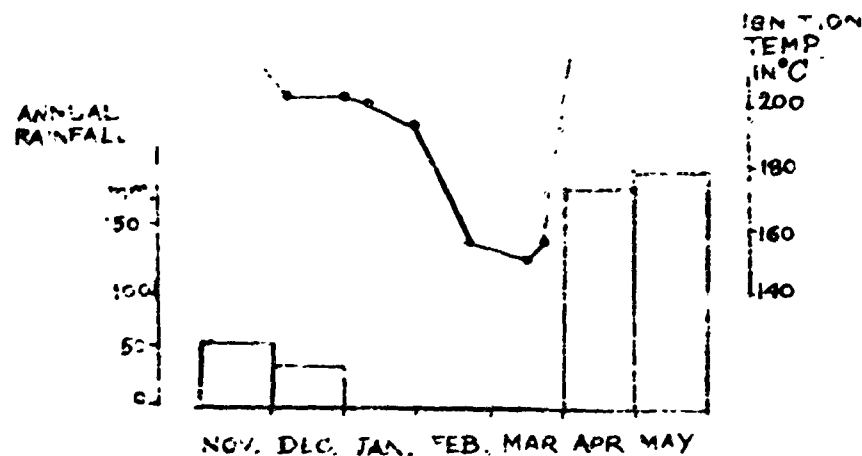


Fig 1. Variation of ignition temperature of Trachypogon spp. (grasses) with monthly precipitation recorded at Bancos de San Pedro, in the Sabana de Calabozo of Venezuela.

After Vareschi, 1962.

As revealed by many studies, fuel moisture content and water in various forms materially affect persistence of fire. Trapnell (1959) in discussing the effects and methods of early burning in a grass and low brush area near Ndola,

Zambia, mentions that it is often difficult to initiate burning early in June (the beginning of the dry season) because fuels are not sufficiently dry. Therefore, burning was light and patchy, skipping more moist grass fuels and spreading with difficulty because the season's dry leaves had not yet fallen to provide a continuous carpet of fuel. Results of experimental burns reported by the Service des Eaux, Forêts et Chasses, Senegal, stress that for a relatively homogeneous grass cover, sustained combustion is also a function of grass height and spatial density, as well as fuel moisture. When hot, dry east winds blew for a few days in October over open savanna woodland near Ferlo, Senegal, grasses withered in less than two days and became highly inflammable. In brushy areas, many plants have aromatic oils rich in oxygen, such as menthol and thynol. Under high heat and within the brush zone, an almost explosive atmosphere can develop and once ignition takes place, intense fire occurs.

Characteristics of the fuel matrix (i.e., fuel size and spatial arrangement,) occurring under southern pine forest of the southeastern United States, permit burning shortly after dry conditions set in. The combination of wire grass and pine needles makes a fine fuel with a large percentage of surface exposure per unit area. Both fuel types are highly inflammable: thus it is possible to achieve sustained combustion in a year's growth only three to five hours following a summer shower.

At the savanna-semi-deciduous forest boundary it has been frequently observed that fire spreading into the forest from nearby grasslands burns out after penetrating less than 10 meters. Here, the presence of moisture under a forest micro-climate dampens the fire with amazing suddenness, since much of the heat generated at the ground is utilized in transforming water in the fuels to steam. There results a significant loss of oxygen to feed the flame, so

that a lowering of fire temperature occurs to values too low to sustain combustion. Most cool surface fires typical of moist tropical forest environments are not self-sustaining without an accumulation and drying of slash.

2. Propagation of Fire and Rates of Fire Spread

Many factors of the natural environment relate directly to successful propagation of fire with forward movement of a fire front. In addition to the factors of fuel inflammability, fuel size, and composition, it appears that dominant factors affecting rates of fire spread are fuel moisture content, fuel quantity, and wind velocity. McArthur (1963) in reporting the results of fire behavior in grasslands of Central Queensland conducted during spring months, presents the relationship between air temperature, relative humidity and the fuel moisture content of a standing grassland (Table 2).

TABLE 2
THE FUEL MOISTURE CONTENT OF FULLY CURED STANDING GRASS-
LAND RELATED TO AIR TEMPERATURE AND RELATIVE HUMIDITY
(fuel moisture content expressed as per cent
of fuel weight)

Air Temp.		Relative Humidity							
°C	(°F)	5	10	15	20	30	40	50	60
10	(50)	-	-	-	-	12.0	13.5	15.0	16.5
16	(60)	-	-	8.5	9.0	10.5	12.0	13.5	15.0
21	(70)	-	6.0	7.0	8.0	9.5	11.0	12.0	13.5
28	(80)	4.0	5.0	6.0	6.5	8.5	10.0	11.0	-
32	(90)	3.0	4.0	5.0	5.5	7.5	9.0	-	-
38	(100)	2.0	3.0	4.0	5.0	6.5	-	-	-
43	(110)	1.5	2.5	3.0	4.0	-	-	-	-

After McArthur (1963)

Fuel moisture content is a very important factor in determining combustibility of green grasslands. The table indicates that for cured grasslands variation in fuel moisture

content related to various air temperatures and relative humidities is rather modest. Rains, dew formation and the occurrence of other weather phenomena assume a more important role than fuel moisture content itself. In cured grasses, the rate of fire spread appeared to be almost directly proportional to fuel quantity and the wind velocity.

The relationship between fuel moisture content, wind velocity and rate of forward progress of a head fire in a fully cured grassland carrying 3 tons of fuel per acre and travelling over level to undulating ground, is shown in Table 3.

TABLE 3
RATE OF FORWARD PROGRESS OF HEADFIRE IN FEET/MIN.
RELATED TO FUEL MOISTURE CONTENT AND WIND VELOCITY
(Fuel Quantity 3 tons/acre)

Fuel moisture content (Percent)		Wind Velocity in the Open (mph.)				
%	5	10	15	20	25	30
2.....	55.0	132.0	264.0	440.0	671.0	968.0
4.....	39.6	99.0	198.0	330.0	506.0	715.0
6....	29.7	79.3	148.5	253.0	396.0	561.0
8.....	23.1	60.5	115.5	203.5	297.0	429.0
10....	18.7	47.3	93.5	154.0	236.5	330.0
15....	9.9	24.2	46.2	79.2	121.0	176.0
20....	5.5	13.4	24.2	44.0	66.0	88.0
25....	-	6.6	13.2	22.0	33.0	49.5
30...	-	-	6.6	13.2	18.7	26.4

After McArthur (1963)

The quantity of fuel in a grassland assumes an important role in fire spread. Three tons per acre is a heavy cover for much of the tropics, and particularly for Australia.

where it normally is about 1.5 tons per acre. Since the rate of fire spread is directly proportional to fuel quantity, for a fuel quantity of 1.5 tons per acre the rates of spread in table 3 are halved. Experiments indicate that flame height and fire intensity also are directly proportional to fuel quantity. In drought years, fuel quantity in many tropical grasslands may not exceed 0.25 to 0.5 tons per acre. Under such conditions, a grass fire will not spread faster than 1 to 2 mph under the worst possible fire weather conditions, and flames are virtually invisible.

As noted, values for fire spread are based on observations made of burning on level to undulating terrain. Where perceptible slopes exist, marked variations in rates of fire spread occur. McArthur found that for the same fully-cured fuel quantity per acre, rates of fire spread up a 10° slope were double those indicated in the table; for a 20° slope, rates were increased fourfold. Under extreme fire weather and ample fuel conditions of homogeneous grass cover, maximum rates over steep terrain exceed 30-40 mph. Fortunately, steep slopes have modest lengths so that such rates of fire spread are usually over short distances.

Byram (1958) observed in studies of fire behavior in grass under southern pine in North Carolina the following rates under various wind conditions for both backing fires and head fires (Table 4)¹. Unfortunately fuel quantity was not indicated, but fire spread was measured in grass cover over pine needles.

TABLE 4
FIRE SPREAD IN GRASS COVER UNDER SOUTHERN PINE
(North Carolina)

Type of fire	Backing fires				Head fires			
Wind vel (mph.)	Calm	2	4	6	Calm	2	4	6
Rate of Fire spread in feet min.	1.8	2.0	3.8	4.5	no value given	3.0	30.0	60.0

After Byram (1958)

¹Head fires propagate downwind and back fires spread against the wind

Factors critical to rate of fire spread, also are important influences on the nature of the fire front. Commonly, grass fires are characterized by narrow burning zones, frequently continuous over considerable distances. The overall homogeneity of fuel type and low fuel quantities characteristic of tropical grasslands frequently result in low intensity fires. Single fire fronts not only are characteristic of savanna grassland and parkland, but also of open savanna woodland (or sparsely wooded campo cerrado), if the relative proportion of grass and sedge cover to woody herbaceous species and trees heavily favors the former. In such cases, a surface fire results, behaving primarily in response to conditions of ground cover and weather (PLATE 1).

Propagation of fire in brush and forest is very different than in a predominantly grass cover. The ignition line is carried forward by different patterns of burning at different heights above the ground. One pattern of flame occurs creeping through the refuse on the forest floor, while a different combustion pattern can be observed in the low, dense brush understory. Finally, in the case of fire in tree crowns, a third pattern is present often with flames extending skyward several times the height of the trees. One can only conclude that fire spread depends not only on the total fuel mass per acre and its total surface area, but it also depends on the distribution of this mass and surface area with height, including the randomness of placement of fuel at various levels.

Whereas radiative heat transfer is important in flame propagation in the forest litter, within the brushy understory much heating of unignited fuels occurs through convective action. At this level, the fine structure of the wind carries eddies of flame, or partially ignited gas mixture, that move forward a short distance to bathe a twig or branch. Flame propagation by convective processes increases immeasurably as the wind increases.



PLATE 1: A low intensity surface fire in the campo cerrado, central Brazilian Highlands, as observed from low altitude. Note single fire front, narrow burning zone, and thin smoke plumes (Photo by T. L. Hills).



PLATE 2: Brush fire in early dry season (July) preparatory to cultivation and planting, 25 miles inland from Dar es Salaam, Tanzania. Vegetation being invaded by fire is still green. Note flame height over stacked slash (Photo by I. J. Stolberg).

Another heat transport mechanism, one which varies greatly in importance depending on the gross physiognomic character of the vegetation and the various types of fuels, is that of ignition by fire brands ahead of the continuous burning zone. Fire spotting, by fire brands, has been mentioned as a significant contributor to fire spread in pine plantations of Tanzania, Zambia and Southern Rhodesia. The problem of fire brands is acute in fires under moderate winds in Australian Eucalypt forests, where incidents of spotting nine miles ahead of the fire front have been recorded. In fires started by persons clearing land in dense, moist, semi-deciduous forest, the likelihood of either spotting by fire brands or fire in crowns of trees is negligible. Fires in tall brush and low trees of the woodland and the semi-deciduous open forest, while not necessarily crown fires, do send up rather high flames, the radiation from which is a major contributor to fire spread.

Thus there emerges a picture not of a single fire front moving forward, but two or perhaps three, each of markedly different structure, each propagating forward as a result of the combustion of fuel in its own level of the forest or brush, and of the transfer into it of heat from other levels. In a fire which is advancing steadily through a forest or brush zone, these three regions of combustion move together without change of relative position, unless the physiognomic character of the vegetation changes. Commonly, such changes do occur which render complex any analyses of fire propagation. It hardly needs emphasizing that the basic fire problem is not one of determining the velocity of fire spread, but one of understanding why fire propagates (see PLATE 2).

Ignition and conditions favorable for sustained combustion in forest and brush differ markedly from those of relatively homogeneous, fine fuels found in grasslands. Under dry conditions grasses can be fired and combustion sustained within a brief period following dew or rains. This is not true for forest fuels.

The moisture content of woodland fuels--dead sticks, brush, grass, leaves on the ground or aloft--is an essential factor in determining flammability of forests. Partially counteracting the fairly large fuel quantities normally available, perhaps from 2 tons per acre to more than 30 tons per acre, depending on type of forest, is the need for higher ignition temperatures than for grass. The forest microclimate usually retards evaporation and other forms of moisture loss. If the fuel moisture content of forest litter is 20 per cent or more, the more sensitive kinders are ignited only with great difficulty, and then will tend to only smolder. On the other hand, at five per cent or less fuel moisture content, rapid ignition occurs and active spread of flame ensues. These values of fuel moisture content represent equilibrium with atmospheric humidities of approximately 80 and 20 per cent respectively. In a forest, response of fuels to changes in atmospheric humidity is only minutes for leaves, but hours for twigs, and days for coarser fuels.

Few studies report the relationship between fuel moisture content, wind velocity and rate of fire spread. McArthur (1961) presents empirically-derived values based on experiments conducted in dry sclerophyll, low Eucalypt forest (E. marginata) of Western Australia. The high inflammability of Eucalypt forest has been noted. One may suppose, therefore, that the rates of fire spread may well represent maximum values and that for other types of forest or woodland, rates of fire spread would be much lower (Table 5). As in the case of fine, homogeneous fuels, the effect of fuel quantity on the rate of fire spread in low Eucalypt forest appears to be directly proportional. Under similar meteorological conditions, a fuel quantity of 5 tons per acre would support a rate of fire spread one-half that indicated in Table 5. Fire behavior in slash areas where fuels are stacked results in greatly intensified fires, and no generalization about fire spread can be made.

TABLE 5

RELATIONSHIP BETWEEN FUEL MOISTURE CONTENT, WIND VELOCITY
AND RATE OF FORWARD SPREAD (FEET/MIN.) - FUEL QUANTITY 10
TONS PER ACRE, FUEL TYPE LOW SCLEROPHYLL EUCALYPT FOREST

Wind Velocity in Forest (mph)	Fuel Moisture content (as percent of estimated dry weight)					
	6	8	10	12	14	16
1	7.0	3.6	2.0	1.4	0.9	0.7
2	9.0	4.7	2.6	1.8	1.2	0.9
3	11.8	6.0	3.4	2.2	1.6	1.1
4	15.0	7.7	4.4	2.9	2.0	1.5
5	19.0	9.8	5.6	3.7	2.6	1.9
6	25.0	12.7	7.2	4.7	3.3	2.4

After McArthur (1961)

Biswell (1963) reported on 14 years of experience in using fire in southern California in which fire was used in three vegetation types, chaparral, woodland grass, and ponderosa pine. The first two vegetation types may be considered to have certain aspects in common with types of vegetation in the drier parts of the tropical world. "Chaparral" is derived from the Spanish word "chaparra" meaning scrub oak. It now has been applied to a low, shrubby, dominantly evergreen vegetation, the most important features of which are a deep root system, dense rigid branching and small, thick heavily-cutinized evergreen leaves. The various shrubs form almost a closed canopy so complete as to almost preclude much herbaceous vegetation as understory. Biswell noted that any time that the relative humidity was 25 to 30% and the wind calm, it was possible during the spring season to light a fire at the bottom of a slope and have

sustained combustion uphill, usually dying out at hill crest, despite of rather high moisture content of grasses outside brush areas and budding growth on brush itself. In woodland grass areas composed of pines and oaks with an understory of considerable herbaceous vegetation, sustained burning had to be deferred to drier summer months in order to carry fire under the forest upperstory.

Controlled burning in wire grass and pine needle litter under southern pine in southeastern United States often is undertaken three to five hours following a summer shower. Here, again, the objective is to promote a surface fire of low intensity

The question of minimum fuel quantity necessary to sustain combustion in a forest cannot be answered with broad generalizations. Many comments on minimum fuel quantities are related to experience of persons using fire as a forest management practice to reduce the understory in forest plantations, thereby lessening wild fire hazards. Cooper (1963) in discussing the use of fire in southern pine plantations of Georgia, United States of America, where palmetto-gallberry undercover occurs, noted that at least a ton of fuel per acre distributed fairly evenly was necessary to sustain a surface fire. For low Eucalypt forest, only low intensity fires are possible even under the worst meteorological conditions when fuel quantities drop below 4 tons per acre. When less than 2 tons per acre occurs, sustained combustion is spotty and clean burns are nearly impossible. The changing characteristics of flame height and rate of fire spread under varying fuel quantity conditions have been determined for low Eucalypt forest of Western Australia (Table 6).

TABLE 6

RELATIONSHIP BETWEEN RATE OF SPREAD, FUEL QUANTITY AND FLAME
HEIGHT (in feet)
(Low Eucalypt Forest, Western Australia)

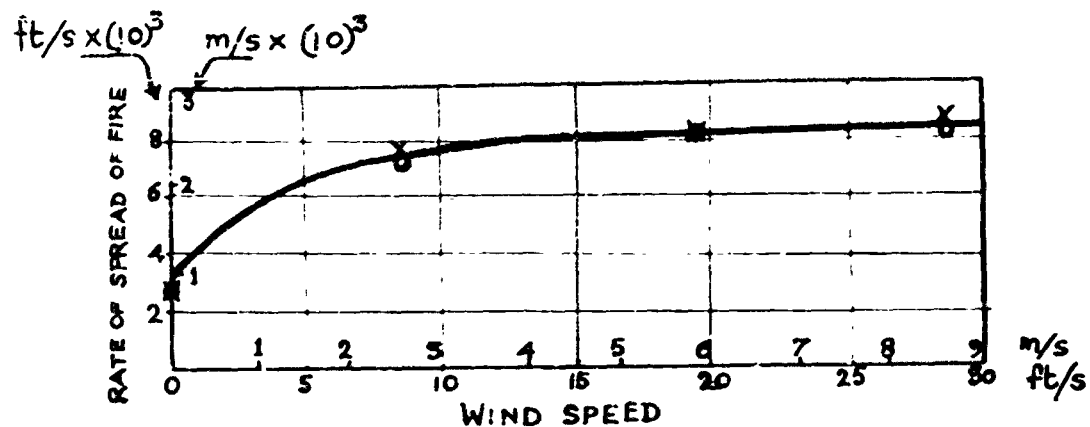
Rate of Spread (feet/min.)	Fuel Quantity (tons/acre)				
	2	4	6	8	10
	Flame Height in Feet				
1	1	1.5	2.0	2.5	3.0
2	1.5	2.5	3.5	4.5	5.5
3	2.0	3.5	5.0	6.5	8.0
4	2.5	4.5	6.5	8.5	10.0
5	3.5	6.0	8.0	10.0	12.0

After McArthur (1961)

3. Laboratory study of Fire Behavior

The number of variables involved in determining fire behavior has made study of fire an incredibly complex task. Experimentation with fire under controlled conditions in the laboratory reduces the number of variables and permits certain simplifying assumptions to be made concerning fire behavior. Many laboratory fires have been studied to determine fire behavior, particularly propagation and spread.

Thomas and Pickard (1961), in laboratory study of the spread of fire in forest and heathland materials, expressed graphically and quantitatively certain aspects of fire behavior. Initial investigation into the effect of wind speed on the rate of spread of fire was made in the laboratory using 10-feet long and one-foot wide wooden cribs made of Parana Pine conditioned at 18.3°C (65°F) and 65 per cent relative humidity. Rates of spread of the front and rear faces of the burning zone were measured over a range of wind speeds from 0 to 30 feet per second (Fig. 2).



X-Front face of burning zone; O-Rear face of burning zone.

Fig. 2 -- The Effect of Wind on the Rate of Spread of Fire.
After Thomas and Pickard (1961)

Plotting the results revealed that although increasing the wind speed increases the rate of fire spread, the effect becomes progressively less as the wind speed increases, while fuel quantity and quality remains constant. Note that the initial difference of rates of fire spread of the front and rear faces of the burning zone gradually coincide within the 10 foot length of the crib. At that point, about two-thirds the length of the crib, the fire becomes two-dimensional. A limited number of experiments with grass and heather gave fire spread rates 10 times larger than for wooden cribs -- probably due to the high surface-to-volume ratio of the natural vegetation.

Investigations were also made into the correlation between flame length and wind velocity, because of the direct effect of flame length on convective-radiative heat transfer ahead of the fire front on unburnt fuels. If such a relationship could be quantified, it would permit a first approximation of the amount of heat transferred ahead of the flame front. If L represents flame length, and D the length of the burning zone in the direction of the wind, statistical analyses of experimental burnings under differing wind velocities indicate that for a given rate of burning, the flame length decreases as the wind speed rises because the mixing rate of

oxygen with fuel for combustion also rises leading to a reduced flame surface. The ratio of L/D is so correlated with the rate of weight loss per unit ground area, wind speed, and length of burning zone in the direction of the wind, as to appear directly related to mass and specific gravity of fuel elements, moisture content, and matrix. Under natural conditions, these cannot be determined with a high degree of accuracy because there is no way to maintain or sustain a set rate of burning. However, laboratory results indicate that the rate of weight loss per unit ground area, and the length of the burning zone in the direction of the wind are related to the rate of fire spread in the form of;

$$m = \frac{WV}{D};$$

where W is the amount of fuel burnt per unit ground area; V is the rate of spread of fire; m is the weight loss per unit ground area; and D is the length of the burning zone in the direction of the wind.

It becomes obvious that these relationships are a first step toward quantification of fire behavior. Before application of laboratory results to field problems, the character of fuels must be quantitatively expressed, as well as the various factors controlling propagation of fire and the processes by which a fire front propagates. The development of fire models to determine the laws of fire behavior is well-rewarding, even though many simplifying assumptions must be made if one is to avoid intractable mathematical equations (see Appendix I). Therefore, attempts to define fire behavior are still at an initial stage. From a developed fire model, one can perform laboratory fires to determine the accuracy of equations as well as refine them. Likewise, the problem is not how to control fires in the laboratory, but rather how to meaningfully separate the complexities of fire behavior in a wide variety of physical situations into entities that can be studied.

4 Fire Intensity

There are relatively few studies of tropical experimental fires ignited under natural conditions where flame temperature at various levels, flame scorch heights and penetration of heat into soil have been measured. Part of the reason is that although fire has long been used as a tool in range and forest management in parts of the tropics, trial and error methods in fire use and protection have permitted application of knowledge gained to successful solution of problems. The need for quantitative data has been expressed by many; written reports reflect direct interest in the effect of flame front on plant conditions and ecological succession as well as the effect of heat on soils.

Temperatures recorded during fires cover a wide range of values as might be expected in experimental fires burned at different seasons, under varying weather conditions, and which included various types and quantities of fuel. Long recognized as among the hottest and most destructive are the heavy slash fires in the coniferous forests of the Pacific Northwest of the United States and Canada. In such fires in Douglas fir, cedar and hemlock temperatures above the ground reached 450°C (850°F) while below 1.9cm (0.75 inch) of duff, temperatures attained 48.4°C (120°F). Perhaps, more nearly analogous to what might be expected in parts of the subtropics. Heyward (1938) reported temperatures of surface fires in longleaf pine of southeastern United States as 65°C to 87°C (150° to 190°F) at the ground surface for a period of only two to four minutes. Bentley and Fenner, (1958) recorded temperatures between 93°C and 120°C (200°F and 250°F) at mineral soil surface when burning grasslands with light litter in western United States, and temperatures below 93°C (200°F) when the land was covered with heavy litter. Where brushland was burned, mineral soil surface temperatures rose to 175°C (350°F). Sampson, (1944) in his study of plant succession in Chaparral bush after burning gives figures for temperature about 1 inch below the mineral soil surface of 158°C to 285°C (320 to 550°F).

Comparison of studies of one area to studies conducted in other areas is unwise because of the number of variables involved. Nevertheless, such studies do indicate the general spectrum of temperatures associated with various fuels. Masson (1949) conducted a series of experimental burns in Senegal primarily to determine the effect of the fires on the soil. To check the instrumentation a small plot about 9 meters square was burnt where the cured grasses 40 to 60 cm (16 to 24 inches) high grew on stoney land. In the first test, wind velocity was high (no value given) and so the test was repeated under the same conditions the same day. The fire lasted 1 minute 20 seconds. In both cases, a maximum temperature at ground level of 105°C (221°F) was reached in the first six to eight minutes of the burns with a rate of cooling off of about 9°C to 16°C (40° to 60°F) in the next six to eight minutes and more gradually thereafter; it must be remembered that the ground was stoney. Repetition of his experiments under conditions of no wind gave maximum temperatures of 200°C (415°F) reached some 10 minutes after ignition. Extension of his experiments to taller grasses 50 to 60 cm (25 to 30 inches) high gave, as would be expected, higher values of maximum temperature at ground level which were reached more quickly (Fig. 3). Wind conditions were light averaging 2 to 3 m/sec.

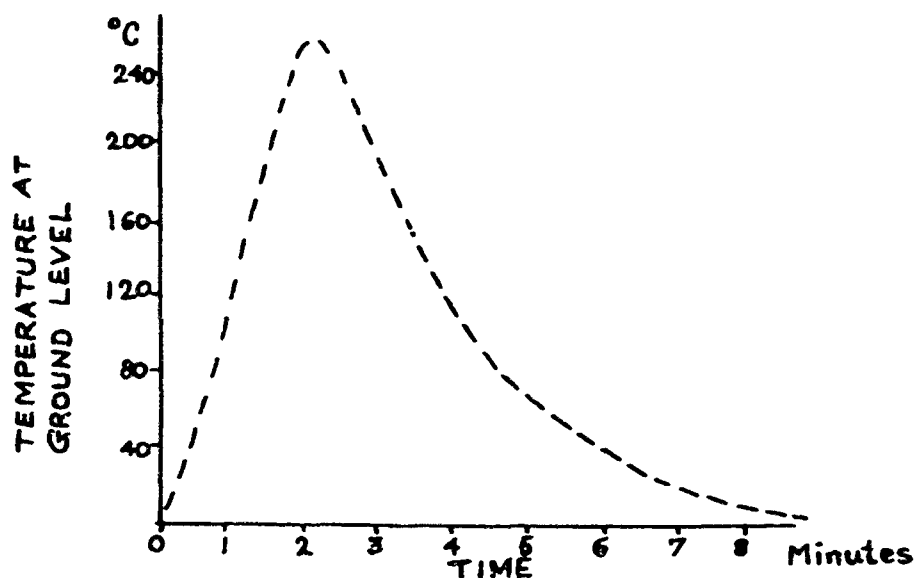


Fig. 3. Temperature profile recorded at ground level during fire passage in cured grass 50 to 60 cm high on sandy soil; wind, 2 to 3 m/sec. Senegal. (After Masson, 1949).

The final experiment was conducted in tufted grasses exceeding 100 cm (40 inches) in height (Fig. 4). Again temperature was recorded at ground level. The soil was sandy and rich in humus and wind variable at 2 to 3 m sec. A maximum temperature of 715°C (1319°F) was reached in one minute and 15 seconds, which returned to the ambient temperature in about ten minutes. Masson concluded that temperatures at the surface during a grass fire depend directly on fuel quantities provided they are in a cured state. In brush fires, the fuel was composed of communities of Gramineae in the Senegalese brush. Higher maximum temperatures at the soil surface in brush fires and an effect of the fire at ground level lasting a noticeable time, were noted, although no attempt was made to relate flame temperature to fuel characteristics and environmental conditions.

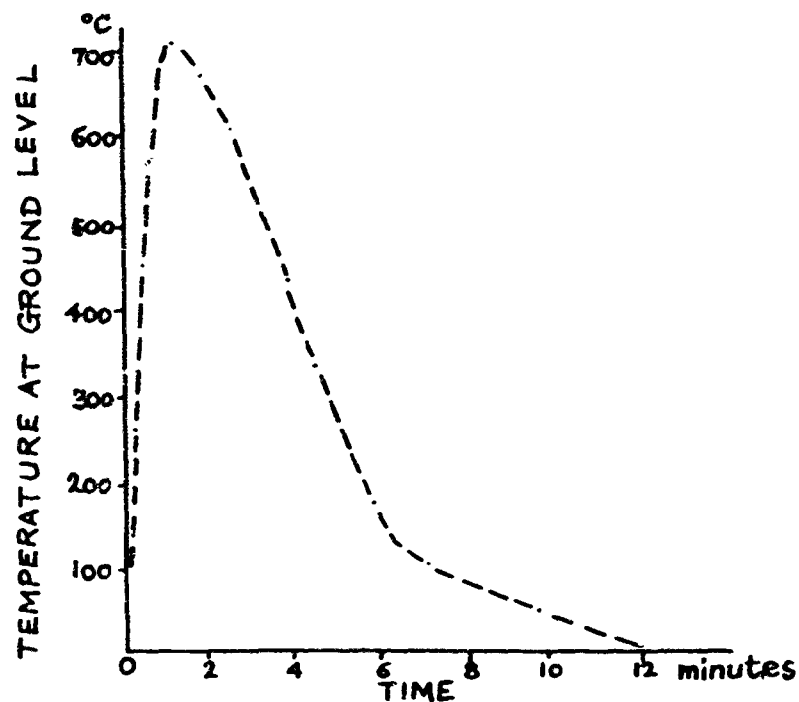


Fig. 4. Temperature profile recorded at ground level during fire passage in cured tufted grass more than 100 cm. high; sandy, humus-rich soil; wind 2 to 3 m sec. Senegal

(After Masson. 1949)

Vareschi (1962), in his study of experimental fire in the Llanos de Calabazo, Venezuela, came to the conclusion that temperatures during the burning stage sweeping over cured grass savanna (creeping *Cynodon*) without herbs, brush or trees, would be 297°C to 392°C (572 to 752 °F), with a possible absolute maximum of about 646°C (1260°F). Although he does not state the height of grasses fired nor the fuel quantity per unit area, it does appear that his observed temperature values are comparable to Masson's study.

Of much more significance, is Vareschi's composite graphic analysis of a typical flame front occurring during burning in the dry season in the Sabana de Calabozo (Fig. 5).

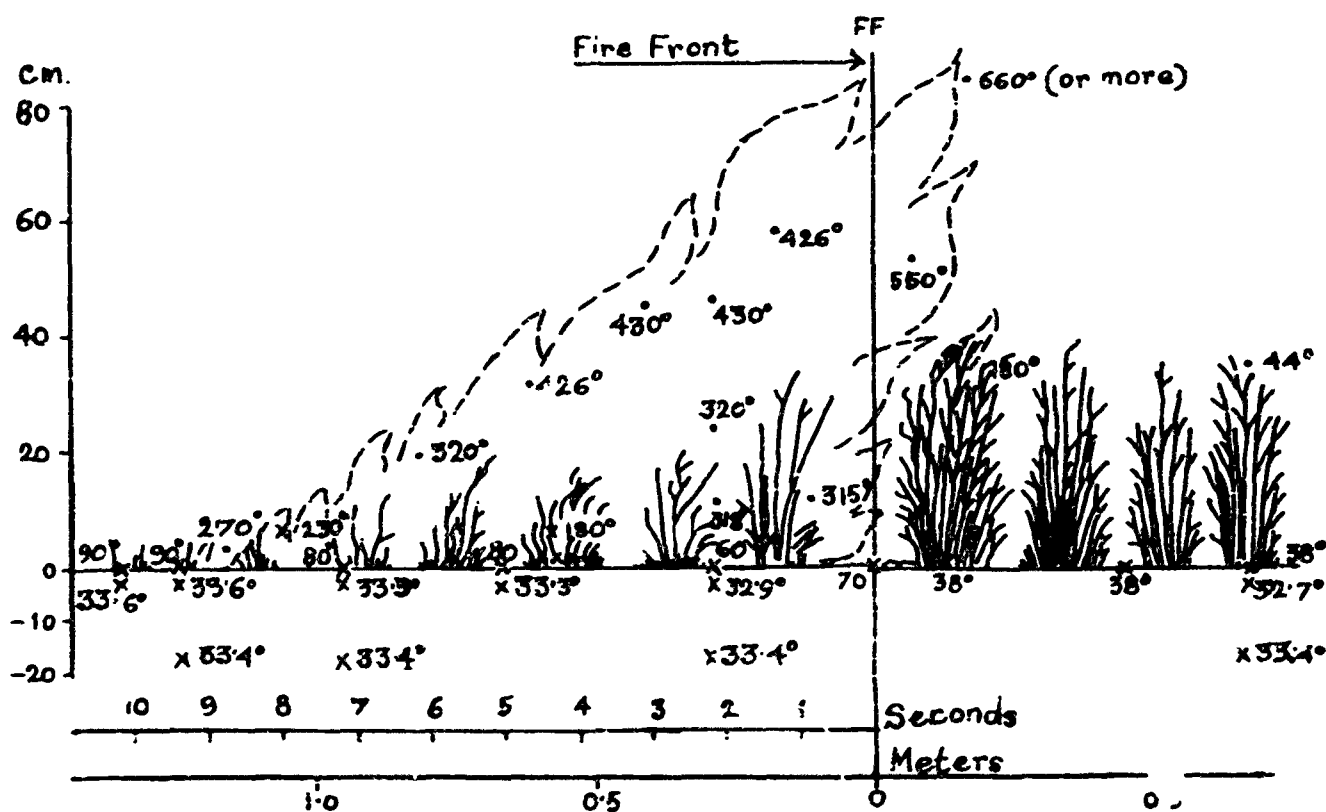


Fig. 5. Thermal structure at the fire front and in the burning zone of a typical fire in fully-cured savanna grass, Sabana de Calabozo, Venezuela.

(After Vareschi, 1962)

Since much of the Sabana is burnt annually, accumulation of fuel is modest. It would appear from the graph that with tufted grasses about 40 cm (16 inches) high probably there

is a cured fuel not exceeding 1.5 to 2.0 tons per acre. The flame height is about 36 inches with maximum temperatures recorded along the forward wall of the fire front increasing from the ground surface upward. Maximum temperature values are 320° to 426°C (608 to 800°F) at mid-flame height, whereas, the temperature gradient is a rapidly decreasing one near ground level.

Surprisingly low temperatures were recorded among the tuft clumps at ground level: 80° to 90°C (176°F to 194°F), comparable to Masson's observations in grasses of similar height. The rather low surface temperatures beneath the flames are an important ecological factor in the survival of seed and new plant buds. The depth of heat penetration into the soil is very shallow and the amount of temperature change is very modest. Absorption of solar radiation on bare ground during the dry season can raise surface temperatures to 60°C (140°F) or slightly more. Therefore, the difference between solar heating of bare soil and the rise of surface temperatures during the passage of a fire having a frontal zone about four or five feet wide is rather negligible.

The increase in soil temperature at 2 cm depth is only a fraction of a degree centigrade. Masson (1949), in his study of experimental burns in Senegal, found that although surface temperatures at passage of fire in brush land may exceed 800°C (1472°F), and that high temperatures may persist for 10 minutes or more, depending on the soil, the penetration of heat below 2 cm depth was slight.

The relationship of fire intensity to fuels and fuel arrangement and rate of fire spread has been empirically determined from repeated experimental burns in Australian Eucalypt forest (McArthur, 1962). The simple empiric equation is.

$$I = Hwv;$$

where I. represents fire intensity in B.T.U. per second per foot of fire front; H. represents heat yield in B.T.U. per

pound of fuel; w , represents the weight of available fuel in pounds per square foot; and r , is the rate of fire spread in feet per second. As the rate of fire spread is directly proportional to the fuel quantity, it follows according to this formula that as the fuel quantity doubles, the fire intensity will increase fourfold.

H , or heat yield in B.T.U. per pound of fuel is not readily determined, since the value of H depends on the heat properties of the fuels present, the various sizes of fuels, and their arrangement. Data derived for Eucalypt forests assume a shrub layer 2 to 3 feet high which contributes approximately 2 tons per acre of available fuel when consumed by fire. To produce a fire intensity of 100 B.T.U.'s per second per foot of fire front, in a fuel quantity of 4 tons per acre, the rate of fire spread would be about 5 feet per minute, whereas for 10 tons per acre, the rate would be only 2 feet per minute. McArthur (1962) notes that fires at I values of 100, are about the maximum which can be considered "two-dimensional" that is, where the depth of convective activity over the fire front is negligible and the width of the burning zone is three feet or less.

The high inflammability of Eucalypt fuels makes it difficult to translate the results of experimental burns in Australia to other types of vegetation in the tropics. However, the relationships between the following fire intensities and description of fire behavior may represent upper limits of combustibility (Table 7).

Martin and Davis (1961) test-burned a number of plots in which temperature profiles against time were recorded for both headfires and backfires under southern pine on the coastal plain of Georgia. The summer burns were in palmetto-gallberry fuels of varying quantity and composition, but all plots had a pine needle mat of varying thickness. Temperatures were recorded at the one-foot and four-foot level. It is unfortunate that winds were neither measured nor reported

TABLE 7

RELATIONSHIP BETWEEN FIRE INTENSITY AND FIRE
BEHAVIOR IN EUCALYPT FOREST, WESTERN
AUSTRALIA¹

Fire intensity B.T.U. sec. ft. of fire front	Flame Height (in feet)	Scorch Height (in feet)	Fire Behavior ²
5 - 12			fires self- extinguishing
13 - 50	1 - 3	6 - 15	surface fire easily controlled
51 - 70	3 - 5	16 - 30	spotting danger present, too severe for some forest species
70 - 100	6 - 12	30 - 45	spotting danger severe, damage to trees pronounced. Danger of damage to canopy.

After McArthur (1963)

¹Data in table 7 is estimated from behavior of fire in a fuel type carrying a shrub layer 2 to 3 feet high which contributes 2 tons per acre of available fuel.

²Description of fire behavior is made in relation to controlled burning practices in Eucalypt forest with mature trees 60 - 100 feet high, and in which fire is used to reduce surface fuel build-up.

in their results; however, the effect of wind is discussed. Temperatures were obtained by iron-constantan thermocouples connected to galvanometers. Temperature profiles were graphed in which the change of temperature was plotted against time measured in seconds. In headfires, temperature rises rapidly to a peak, and as the fire front passes, drops rapidly at first and then at a decreasing rate. The temperature profile for Block 2 plot 3 represents a normal curve for both levels measured (See Fig. 6A, p. 36). Since peak temperatures

at both levels are essentially in phase, it is assumed that winds were light permitting rapid build up to values of 820°C (1508°F) within approximately 45 seconds at the one-foot level, and values of 200°C (392°F) in less than 25 seconds at the 4-foot level. The decline in maximum temperature at the 4-foot level may be due to a number of causes, such as increased convection of air carrying heat away, or variation in wind velocity.

The profile of the burn of Block 3 plot 3 shows clearly the effect of a fast-moving head fire, moving before the wind (Fig. 6B). The wind inclines the flames and convection currents causing earlier peaking at the 4-foot level than at the one-foot level. The fire builds to an equilibrium condition of high fuel consumption rates. Such rapid burning produces high rates of heat yield resulting in high temperatures of nearly equal value at both levels. Such high temperatures permit a wide range of fuel sizes to be ignited simultaneously, which in turn, sustain the high temperatures and heat yields. Maximum temperatures are about 600° - 610°C (1112° - 1130°F) somewhat lower than temperatures recorded for Block 2 plot 3.

Temperature profiles of two back fires, in which the fire front advances into the wind, reflect a slow temperature rise peaking not once, but a number of times at rather low values (Fig. 7A and 7B). Furthermore, maximum temperatures in backfires are sustained longer than is the case in headfires before the temperature begins to fall off. The low rates of heat yield of backfires and attendant low maximum temperatures of 200°C to 260°C (360° - 500°F) are due to slow rates of ignition, in which ignition progresses from finer to coarser fuels under conditions of slower rate of oxygen supply, since convection is limited. Consequently, backfires reach dynamic equilibrium at a much lower temperature level than do headfires.

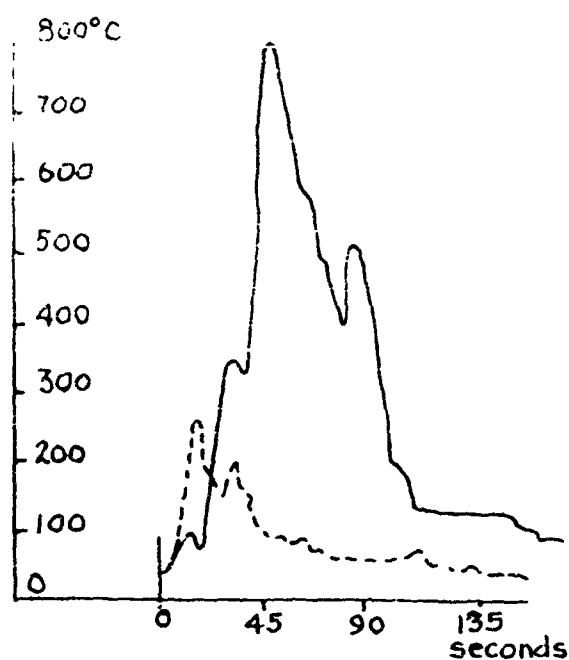


Fig. 6A. Normal headfire t° profile; light wind
Block 2, plot 3.

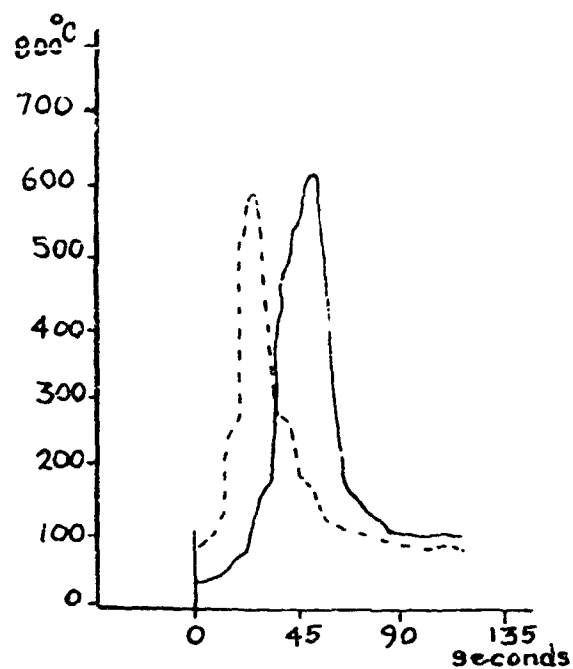


Fig. 6B. Wind-altered headfire t° profile, causing differences in t° values and peaking.
Block 3, plot 3.

TEMPERATURE PROFILES OF SUMMER BURNS

PALMETTO-GALLBERRY FUELS
Alapaha, Georgia 1959

— 30.5 cm. (1 foot) level
--- 121.9 cm. (4 foot) level

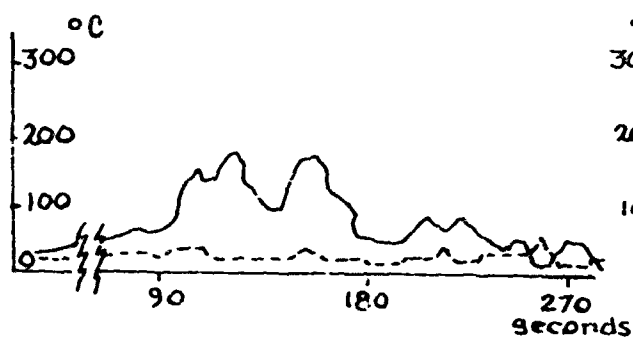


Fig. 7A. Backfire t° profile.
Multiple peaking and low t° values, light wind.
Block 1, plot 3.

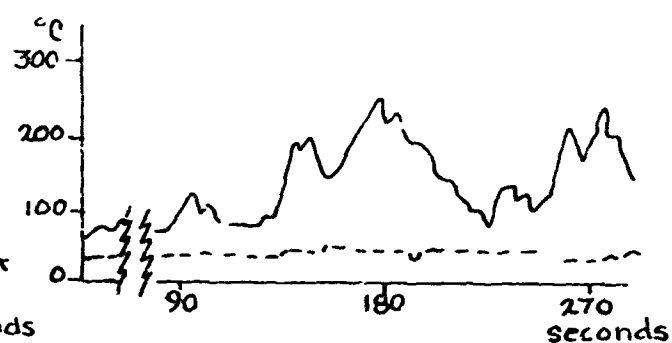


Fig. 7B. Complex backfire t° profile - wind altered.
Block 2, plot 3.

(After Martin and Davis 1961)

Although results of test-plot burns in palmetto-gallberry fuels may not represent fuels typical of much of the tropics, it is noteworthy that the temperature profiles appear to agree in general with results obtained by other investigations of fire in the tropics. Most uncontrolled tropical fires are headfires, exceptions being the use of fire to prepare fire breaks, or fire used as a land management tool by competent persons. Since much burning occurs at the end of the dry season in the wet-and-dry tropics, fuels are fully cured. It appears that maximum temperatures obtained in headfire tests by Martin and Davis more nearly resemble those recorded for brush savannas rather than pure grasslands. The effect of a southern pine canopy may be rather modest because of the physical character of palmetto-gallberry fuels and the high combustibility. If this assumption is valid, then the temperatures of 400° to 800°C (752° to 1472°F) measured by investigators burning brush in African savanna woodland are too low. It has been suggested by a number of investigators that fire-resistant species can comprise a significant portion of this type of vegetation, and therefore, fuels available for combustion may actually be less than in the case of palmetto-gallberry fuels.

In moist, dense semi-deciduous forest and tropical rainforest, fires are all surface fires in which temperatures are low. Sustaining combustion often is difficult owing to the factors of widely variable fuel size and composition, varying rates of fuel moisture, and other local environmental conditions. Repeated burning of forest clearings preparatory to planting in order to produce enough ash and cleared land for cropping is widespread in tropical rainy climatic areas. Few climates are so wet as to preclude the use of fire. Burning requires the piling of slash and a varying period of drying, depending on climatic conditions, prior to firing the cleared plot. Under these conditions, the behavior of fire is not a serious problem, and if the fire front should enter the forest, it frequently is extinguished after penetrating only a few meters.

5. Smoke and Visibility

Few references among the many pertaining to fire in the tropics mention the color and behavior of smoke, or seasonal variation of visibility. This is not surprising since the number of variables which contribute to characteristics of smoke are exceedingly large. Some of the factors of known importance are fuel type and quantity, characteristics of fuel arrangement, fuel moisture content and condensed water in the fuel matrix and intensity of the fire. Important environmental conditions would be those factors contributing to combustibility, such as wind velocity and height of temperature inversion, and to fire spread, such as terrain and so forth. The number of possible interrelationships among the various factors is almost infinite.

Generally, low intensity fires are characterized by pale or white smoke; the opacity of the whiteness of the smoke is directly related to fuel and environmental conditions. Under low intensity fires, temperatures along the flame front are able to ignite only the finer fuels. If fuel moisture content is appreciable, or rains or dew formation are recent much of the heat at the fire front goes to generate steam which contributes to the whiteness and opacity of the smoke column. Most fires in the tropics are surface fires. "Cool" fires are more characteristic of open savanna which has a fairly homogeneous fuel matrix. Although rates of fire spread may be high as the relatively narrow burning zone proceeds downwind, generally the smoke column is pale or white in color, leaning downwind and rising to relatively modest altitudes (PLATE 3).



PLATE 3: Fire and smoke plumes in open park savanna of the Llanos, Apure State, Venezuela. Note gallery forest and second fire in center of photo near horizon (Photo by T. L. Hills).



PLATE 4: Poor visibility and destruction immediately following fire in the arid wooded savanna typical of parts of Southern Rhodesia (Photo by P. E. Glover).

Poor visibility due to smoke concentrated in low levels of the atmosphere has been noted in many places in the tropics. The customary burning of the fields in southern Sumatra around Palembang resulted in disrupted flight service to that city because of smoky haze as recently as September-October 1964. Numerous casual references relate poor visibility, viewed both from the air and on the ground, in central Brazil, Colombia and the Venezuela Llanos, to widespread burning at the end of the dry season. Smoke plumes rising to more than 10,000 feet elevation in Senegal and Tanzania have received comment in literature on fire. Unfortunately, very little information is available which would identify in more than general terms, the variables and combinations of variables that favor the onset of poor visibility due to smoke.

The relationship of the quantity, type and spatial distribution of fuel to single or multiple fire fronts and other characteristics of fire, has been examined above. Although grass fires may have narrow burning zones and low fuel quantities per unit area, a great deal of smoke may occur depending on the moisture content of the fuels and the area burned. Frequent references note grass fires sweeping uninterruptedly for miles (see PLATE 3).

In savanna woodland, multiple fire fronts and spotting ahead of the general fire area are likely, because there exists a wide range of fuel types and sizes. Grasses, herbaceous growths and low trees burn at different rates. Consequently a large area swept by fire would continue smoking for a considerable period of time due to smoking logs and isolated fires (see PLATE 4). Where fuel quantity is low, on the other hand, the fire may be two dimensional, producing a narrow burning zone and little smoke (see PLATE 1).

Fires in moist tropical forests are limited in areal extent, and rarely spread much beyond the zone cleared for planting (see PLATE 24, p. 145). The total amount of smoke contributed to the atmosphere would depend on the cultural practices

and agricultural calendars employed by the people. The total number of fires in an area depends in part on the population density and the length of the forest-fallow period. Another important variable, is that no dry season occurs; thus rain showers during the drier period remove smoke from the atmosphere.

Smokiness also is related to meteorological conditions that limit dispersion of smoke to the lower layers of the atmosphere. Frequently during the dry season, air masses are highly stratified with marked vertical variations in temperature and moisture. Temperature lapse rates at low levels usually are fairly steep due primarily to surface heating. Smoke plumes rise rapidly for the first 3,000 to 6,000 feet of elevation, only to spread laterally along the base of a temperature inversion. The strength of the inversion and the mean height of its occurrence depend on many factors, such as air mass characteristics and air mass modification as it traverses a region. It has been observed that poor visibility frequently occurs for periods of a few days to a week or more. Presumably, persistent low level inversion, coinciding with widespread burning at the end of the dry season, does occur with significant frequency in many parts of the tropics.

Intense fires are more likely in the forest-savanna boundary and in savanna woodland. The relatively large fuel quantities present promote combustion and permit higher temperatures in the burning zone. Consequently, a wide range of fuel sizes is readily ignited, and carbonization of fuels under high heat results in darker tones in the color of smoke. Naturally convection is active and the smoke rises rapidly, often to great heights. That rather intense fires occur in Chad, Sudan and Senegal in savanna woodland and along the forest-savanna boundary is evident from accounts of well-defined convection columns carrying smoke skyward 3,600 feet in less than six minutes.

C. Conclusions

The number of variables involved in determining fire behavior is so large as to make it impossible at the present time to predict with any degree of certainty what will occur when an accidental fire is ignited. Generally, an empirical approach has been and is used in the study of fires in the tropics. Frequently, one idea and then another has been applied to see which one works best. The experience gained from repeated experimental fires has been satisfactory in solving some of the problems associated with fire, both as an enemy and as a servant.

The main variables affecting fire behavior are:

1. fuel size, quantity and spatial arrangement;
2. fuel moisture content, both chemisorbed and present as condensed water in the fuel matrix;
3. terrain, particularly slope;
4. wind velocity;
5. the transport of burning embers -- the spotting process; and
6. atmospheric conditions, especially the temperature and dew point lapse rates, particularly at ground level, but also within the first 5,000 feet.

This list of factors is by no means complete. Fortunately many of the variables assume importance only under extreme fire behavior conditions, especially those factors affecting the process of energy release and convection formation. In the tropics, burning in forested environments is generally limited to control burning policies or to clearing land for cultivation. In both cases, the goal is to obtain a low-intensity ground or surface fire. Fires in grasslands often are free-burning, but here the available fuels are less than those available in forested environments. Consequently, the general intensity of such fires is not high, even though their frequency of occurrence and the extent of area burned annually may be large.

Areas in which basic studies would contribute most significantly to an understanding of fires, actually are the same ones identified as being significant factors in fire behavior. Of utmost importance, however, are those factors pertaining to sustaining combustion and fire spread. Inadequate information is available on gas and flame emissivities as a function of frequency at high temperatures. Mathematical techniques also must be developed for prediction of the radiation emitted by distributed sources and transmitted through absorbing gases. These data and techniques are necessary in order quantitatively to determine the radiant heat transfer which has a large influence on the rate at which fuel becomes available to the fire.

The model laws for aerothermodynamic systems in which the fuel consumption rate is dependent on and is controlled by the heat evolution rate should be determined. Parameters to be studied include: effects of geometry, fuel type, radiation, and heating rates. Types of fire-front propagation should also be studied, e.g., continuous flame fronts or discontinuous sources of ignition distributed by aerodynamic forces.

Fundamental information on the aerodynamic properties of burning bodies in motion is needed. The available scanty information indicates that burning decreases drag. The magnitude of this effect and its connection with the aerodynamic pickup and transport of embers is unknown.

Consequently, it is impossible to predict with certainty the chances of fire spotting ahead of a flame front or the course of the fire.

The convection of air and hot gases associated with a liberation of heat has two aspects: 1) the general rising air currents; and 2) the local gas movements in and near the heat source. Convection currents are modified by interaction with winds, topography and turbulence. The local motions are the result of interaction of the broader scale convection with those currents due to gas expansion associated with

combustion. The quantitative and in most cases, the qualitative features of these convection currents and their role with respect to burning are unknown.

Study of naturally occurring fires indicates that much information is needed. Factors to be measured in the atmosphere at all significant elevations might include: 1) wind speed and direction; 2) turbulence; 3) temperature, including lapse rates and dew point temperatures; 4) air moisture; and 5) cloud activity. Time-lapse photography would provide an excellent continuous record of convection column, smoke and fire behavior, particularly if the film were keyed to a time scale.

REFERENCES CITED

- Bentley, J. R. and R. L. Fenner (1958) Some temperatures during burning related to post fire seed beds on woodland range, Jour. Forestry, 56:737-774.
- Biswell, H.H. (1963) Research on Wildland fire ecology in California, Tall Timbers Fire Ecology Conference, Second Annual, March 1963, pp. 63-97.
- Byram, G. M. (1958) Some basic thermal processes controlling the effects of fire on living vegetation, Research Notes South Eastern For. Exp. Sta., No. 114, 2 pp.
- Cooper, R. W. (1963) Knowing when to burn, Tall Timbers Fire Ecology Conference, Second Annual, March 1963, pp. 31-34.
- Heyward, F. D. (1938) Soil temperatures during forest fires in the longleaf pine region, Jour. of Forestry, 36:478-491.
- Martin, R. E. and L. S. Davis (1961) Temperatures near the ground during prescribed burning, Papers of the Michigan Acad. of Sci, Arts and Letters, Part I: Natural Science, 46:239-249.
- Masson, H. (1949) La temperature du sol au cours d'un feu de brousse au Sénégal, Bul. Agric. Congo Belge 40:1933-1940. (Also: Agron. Trop. 3:174-178 (1948).
- McArthur, A. G. (1961) Fire danger rating table, for annual grasslands, Forestry and Timber Bureau, Annual report for the year 1960, pp. 10-12.

- McArthur, A. G. (1963) Revised forest fire danger tables. Forestry and Timber Bureau, Annual Report for the year 1962, pp 7-8.
- Sampson, A. W. (1944) Effect of chaparral burning on soil erosion and on soil moisture relations, Ecology, 25, No. 2:191-195.
- Sénégal (n.d.) Nature et caractéristiques du feu de brousse au Ferlo, Rép. du Sénégal. Ministère de l'Economie Rurale, Service des Eaux, Forêts, et Chasse, Dakar, 42 p.
- Thomas, P. H. and R. W. Pickard (1961) Fire Spread in forest and heathland materials, in: Report on Forest Research for the year ended March 1961, pp. 105-108.
- Trapnell, C. G. (1959) Ecological results of woodland burning experiments in Northern Rhodesia, Jour. of Ecol., 47:129-168
- Vareschi, V. (1962) La quema como factor ecologico en los llanos. Boletín de la Sociedad Venezolana de Ciencias Naturales 23, No. 101:9-31

CHAPTER III

FIRE AND THE PHYSICAL ENVIRONMENT

A. Introduction

The interaction of fire with the physical environment both modifies that environment and those conditions of the environment favoring occurrence of fire. Frequent fire in a given area alters its ecological balance, with progressive change toward environmental conditions which appear to favor more frequent and widespread fire. If this is true for most parts of the tropics, then fire, from both natural and cultural causes, is one of the more important physical agents able to initiate profound and lasting changes in the physical landscape. Whether the total effect of fire over long periods of time is degradational, causing deterioration of vegetative cover and soil-water relationships, depends on the degree to which accidental fire is reduced and prescribed burning is consistent with known facts concerning induced fire-changes.

It is recognized that repeated occurrence of fire in an area initiates successional change in the vegetative cover in which fire-resistant species become dominant. Likewise, vegetation changes are accompanied by micro- and topoclimatic changes, which in turn affect soil moisture, surface and ground water supplies and other variables. Thus one should conceive the presence of fire in the tropics as a physical agent in the same sense as one considers precipitation, lightning, or soil microorganisms. Furthermore, fire is an integral part of the total ecological system, which would include not only the myriad aspects of the physical environment, but the cultural environment as well. The role fire plays in this encompassing ecological view, and the

magnitude and direction of its effects on the total environment, are identified only in the broadest terms. Appeals for detailed and quantitative information on the effects of fire are prevalent in the literature.

To simplify the problem of the interaction of fire with the environment, the physical environment has been separated from the cultural environment, each to be treated in some detail (see Chapter IV). The occurrence and frequency of fire in an area is more likely to be due to cultural rather than natural causes. The reader is cautioned, therefore, to recognize the interrelationship of two rather arbitrarily separated spheres of the total tropical environment.

A topical organization is employed here in presenting the interaction of fire with the physical environment. It is important to recognize that many of the effects of fire reported in the literature in one area cannot be extrapolated to other tropical areas. For example, soil water and ground water conditions and successional change in vegetation are phenomena restricted in area. Only the broadest generalizations are possible for the entire tropics. One should not assume, that the topics treated represent an implied order of significance or are the most dominant effects. Rather, they reflect the research interest and biases evident in the literature. Finally, exhaustive treatment of each topic is not attempted, but rather to indicate latest information and the direction and conclusions of the various sources used.

The interaction of fire with the physical environment is organized around the following topics: 1) fire and atmospheric conditions, including climate and aperiodic weather; 2) fire and natural vegetation, including ecological effects and successional change; and 3) fire and its effects on selected aspects of the environment, including soils, edaphic considerations, and biota.

B. Fire and Atmospheric Conditions

1. Atmospheric Influences on Fire

The most significant relationship between fire and atmospheric conditions is the occurrence of a number of variables that combine to produce highly inflammable fuels and an explosive atmosphere. Lack of precipitation, low absolute and relative humidity, high fuel and air temperature, moderate winds and a high rate of evaporation, all contribute to the conditioning of fuels to low ignition temperatures. Most fire danger rating systems employed in Australia, India and other parts of the world use the above criteria in various ways in order to predict fire. Nearly all systems are empirical and restricted in areal usefulness because the value for each criteria employed represents a regional application of climatic and meteorological data to fuel conditions in major types of natural vegetation (see Chapter II).

For many parts of the tropics, the incidence and danger of fire coincide with a definite climatic dry or drier season. Climatically, the recorded annual rainfall and overall seasonality are less significant than the occurrence of a dry period and its duration and intensity. What constitutes a dry season potentially high in fire danger depends on many factors and is not easily determined. On one hand, the climate must be characterized by rainfall sufficient to support fuel quantity, type and spacing adequate to permit sustained combustion and fire spread. On the other hand, a drier period must occur of sufficient intensity and duration to permit burning. As mentioned previously, fire is frequently an annual occurrence in semi-arid tropical climates where annual precipitation may be as low as 41 cm. (16 inches) and 6 to 8 months of severe drought occur. Even though tufted grasses, low herbaceous plants and widely scattered clumps of brush and trees are separated by considerable distances of bare ground, fire has been reported.

Perhumid tropical climates, in which fire is virtually impossible owing to excessive well-distributed rainfall and high atmospheric humidity, are limited areally. Typical sites would be mountain and plateau slopes transverse to prevailing onshore moist winds. An example is the Pacific coast of Colombia where at Andagoya, elevation 71 meters, annual precipitation is 7,089 mm. falling on 303 rainy days per year, and in which no month has fewer than 21 rainy days (West, 1957). Here, land is cleared by felling and piling brush, which under existing extreme conditions of moisture and humidity, is reduced by microbial activity in a few years. Along Caribbean Costa Rica, however, it has been recorded that certain tree species lose their leaves when monthly rainfall falls below 13 mm. even though annual precipitation varies from 3,700 - 5,800 mm. along the coast. Furthermore, in the humid and rainy parts of the Congo River Basin, slash and burn agriculture is practiced even though felled trees and piled limbs and brush are left to dry a month or slightly more prior to burning. In this case, the forest bioclimate is completely altered by opening the forest canopy. Consequently, piled slash will dry out even though the land may be cleared at any time. The slash is burned, on any clear day.

Numerous factors other than the seasonal march of temperature and precipitation are important in establishing the characteristics of the dry period. Soil texture and permeability and soil moisture storage capacity, as well as the mean depth of subsurface water are significant edaphic factors. Evaporation from surface soil has been measured at tropical experimental stations. In nearly all cases observed results can be extrapolated to other areas only with caution. Thus, in the absence of better information applicable to large areas, climatic data have been the primary source of empirical relationships established to determine the length and severity of a dry season. Since no one boundary coincides

with onset of dryness, a fundamental problem is to establish the threshold through which water formerly freely available for plant growth is replaced by water need. Once a threshold has been established satisfactory to a meaningful interpretation of the observed response in natural vegetation, the date and duration of a dry period can be identified from climatic data. Since the severity of drought is accumulative and progressive, a second problem is to indicate by some means the magnitude of the water deficit. (see sec. 2 a).

2. The Climatic Dry Season

Two methods for determining climatic dry season, each very different from the other, have been selected for comparative analysis. The more complex and sophisticated water balance method employed by C. W. Thornthwaite Associates (1955) has the merit of quantitatively expressing water utilization, deficit and surplus for any location for which monthly temperature and precipitation data are available. Also widely used is the simple and easily applied criteria proposed by the noted French geobotanist H. Gaussen and evaluated by the German ecological botanist H. Walter (Bagnouls and Gaussen, 1953, 1957; Gaussen, 1954; and Walter, 1955, 1958). Both methods are applied to 13 climatic stations, four in Latin America, five in Africa, and four in tropical Asia. Care was taken to select stations representative of the expected types of tropical climate within the limitations imposed by available data.¹ For each tropical area, there-

¹C. W. Thornthwaite Associates, Centerton, New Jersey, have published a series of volumes entitled Average Climatic Water Balance Data of the Continents. For stations listed, location, elevation and length of record are presented. Average monthly and annual totals, where applicable, of potential evapotranspiration, precipitation, soil moisture storage, actual evapotranspiration, water deficit and water surplus are given for each station, all values being expressed in millimeters.

Most of the data used for the preparation of the climographs utilizing the method of Bagnouls and Gaussen were from: F.L. Wernstedt, (1961) World Climatic Data, (Latin America and the Caribbean, Africa). Department of Geography, Pennsylvania State University.

fore, four or more stations roughly along a latitudinal traverse line were selected. Two climographs, illustrating the two methods, were constructed for each station (Figs. 8 through 14). It was not our purpose to evaluate the climates represented by the climographs, but to compare the ability of the two methods to identify and determine the characteristics of a dry season, if present, in relation to potential combustibility of natural fuels.

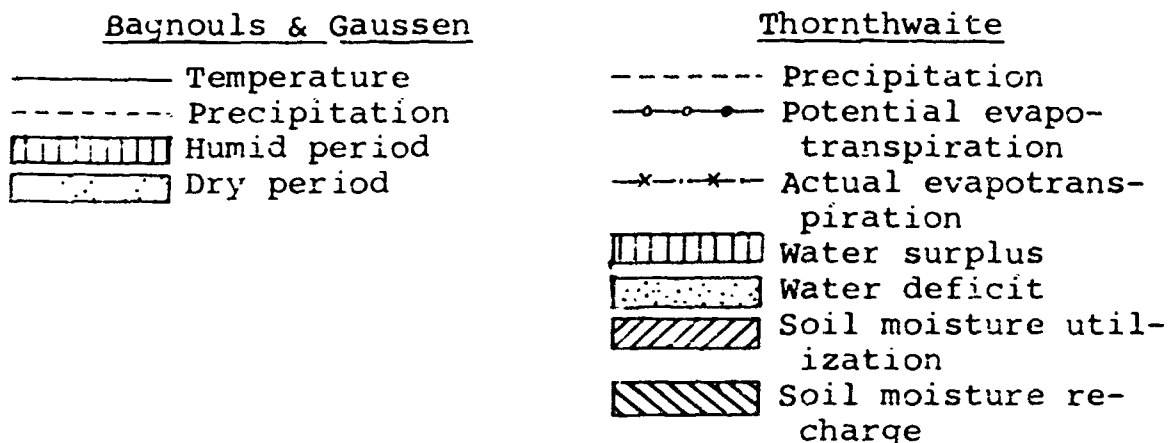
a. Dry Season as Determined by Climatic Water Balance.--
Thornthwaite (1948) introduced the term potential evapotranspiration which was empirically derived from temperature data and expressed in units of water need. If the amount of water available in a climate was unlimited, potential evapotranspiration (PE) expressed as average monthly values of water need, represents potential moisture loss by the various physical processes as determined solely by the climate. When PE is plotted against recorded precipitation, the gross features of the seasonal water balance are identified. Actual evapotranspiration, however, varies constantly, and it is related to a number of variables, particularly soil moisture. Unable to determine the constantly varying water loss by vegetation as related to soil moisture, Thornthwaite developed a model which permitted the first 10 cm. depth of water in the root zone to be lost at the potential rate. Actual evapotranspiration would decline to zero after 10 cm. have been removed from the soil. A water surplus would occur whenever there was precipitation greater than the 10 cm. of soil moisture recharge, while water deficit would occur when water need (PE) exceeded precipitation following the exhaustion of 10 cm. of soil moisture. Using this essentially bookkeeping procedure, quantitative values of moisture balance could be obtained.

The solution of the problem of determining actual water loss by vegetation or actual evapotranspiration (AE) has remained elusive. Thornthwaite and Mather (1955) modified the system whereby: "a) the available soil moisture storage can vary, depending on the vegetation cover and the

(to p. 60)

THE CLIMATIC DRY SEASON

The determination of the dry period according to Bagnouls and Gaussen formula [$P_{(mm.)} \leq 2T_{(°C)}$], left, and Thornthwaite's Water Balance, right.



Note: In some climographs the vertical scale above 200 mm. has been adjusted.

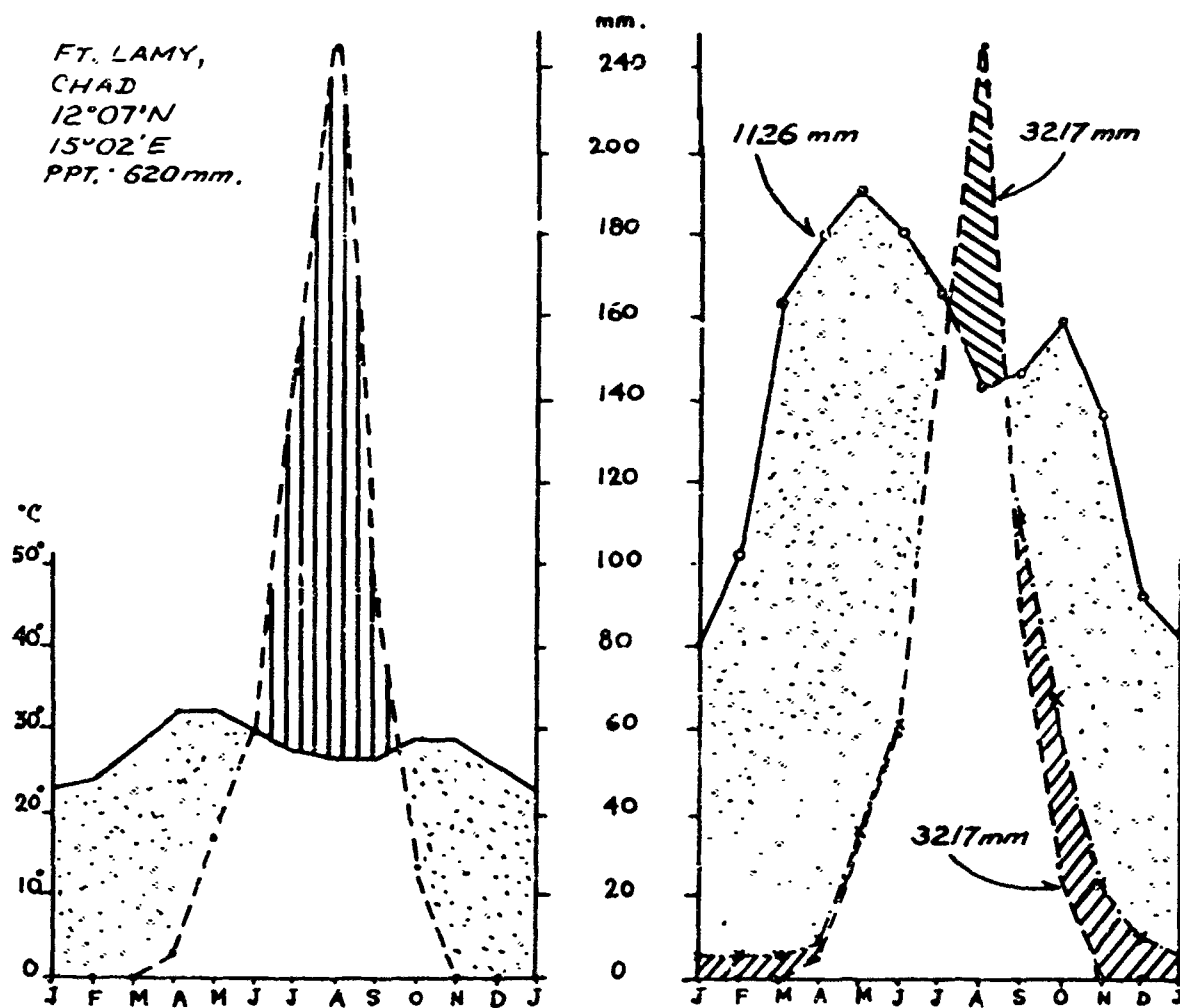


Fig. 8

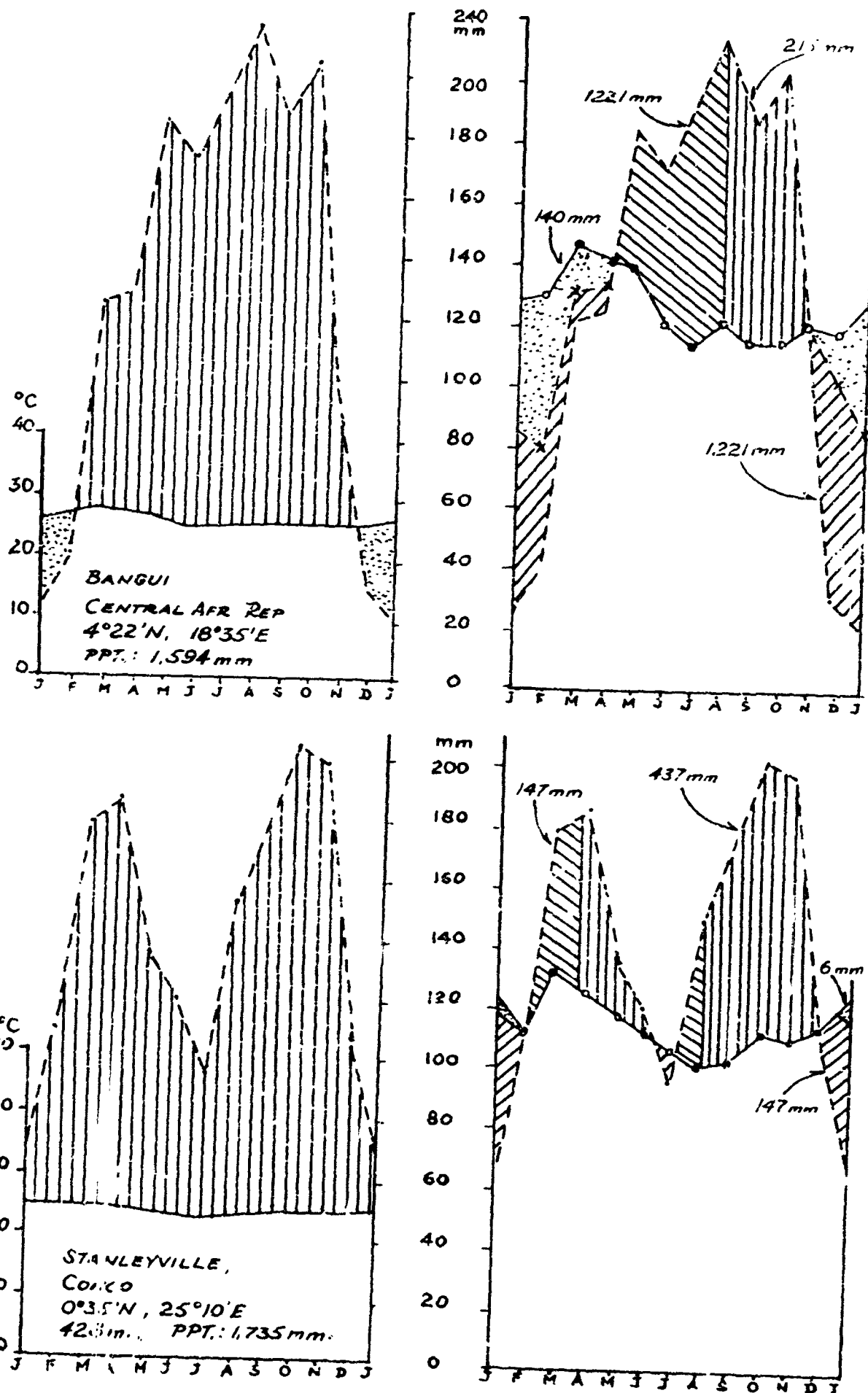


Fig. 9

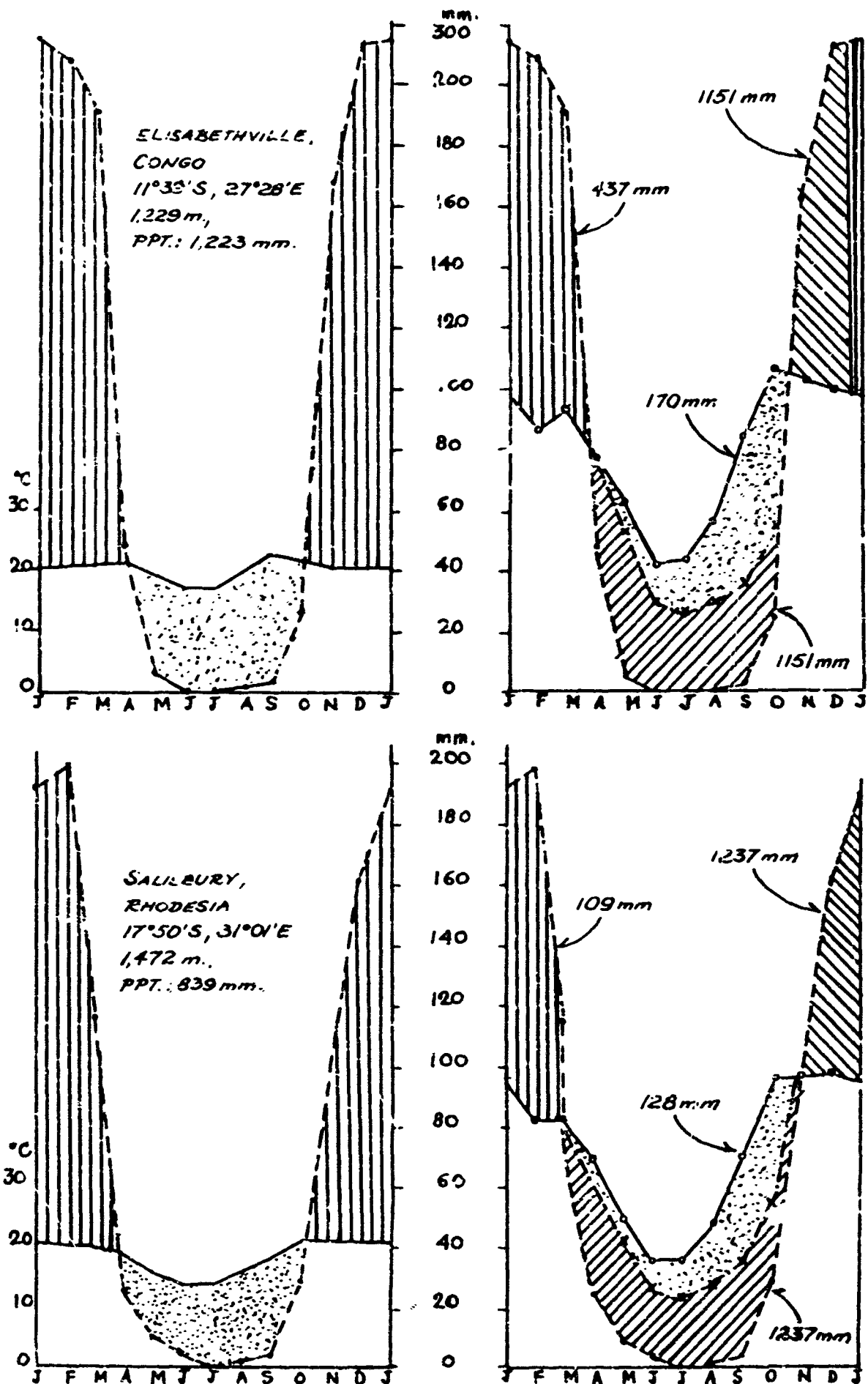


Fig. 10

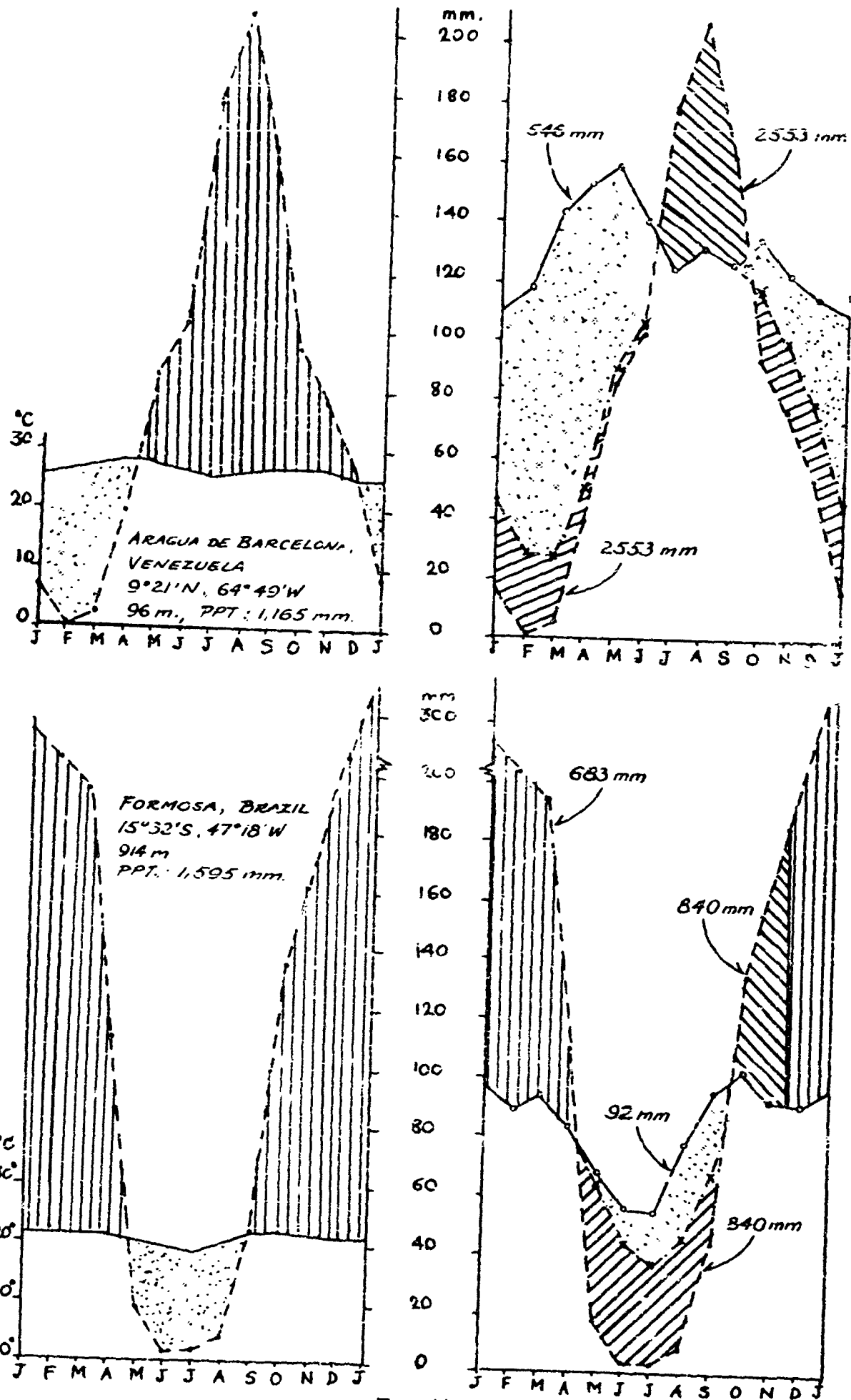


Fig. II

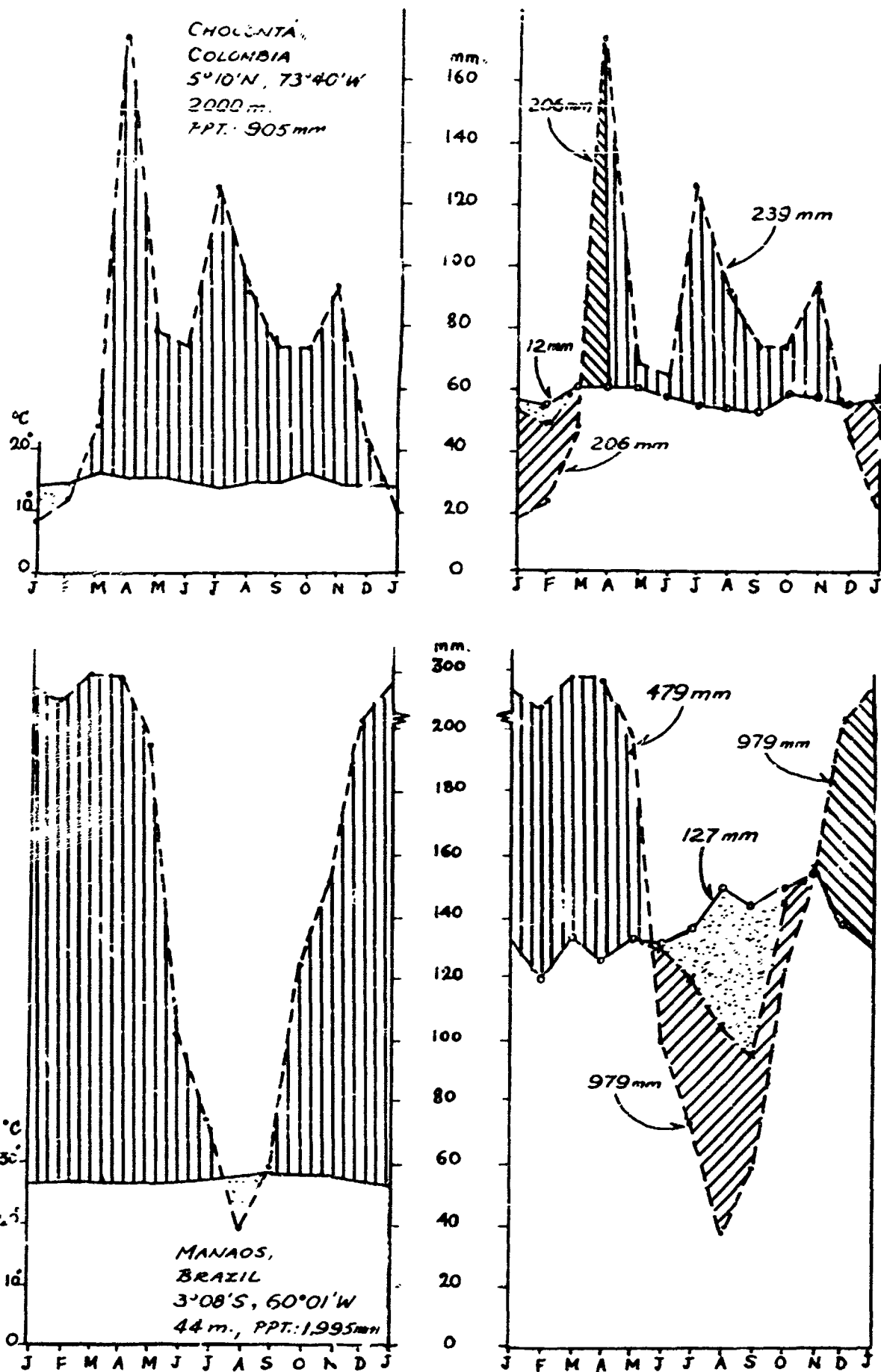


Fig. 12

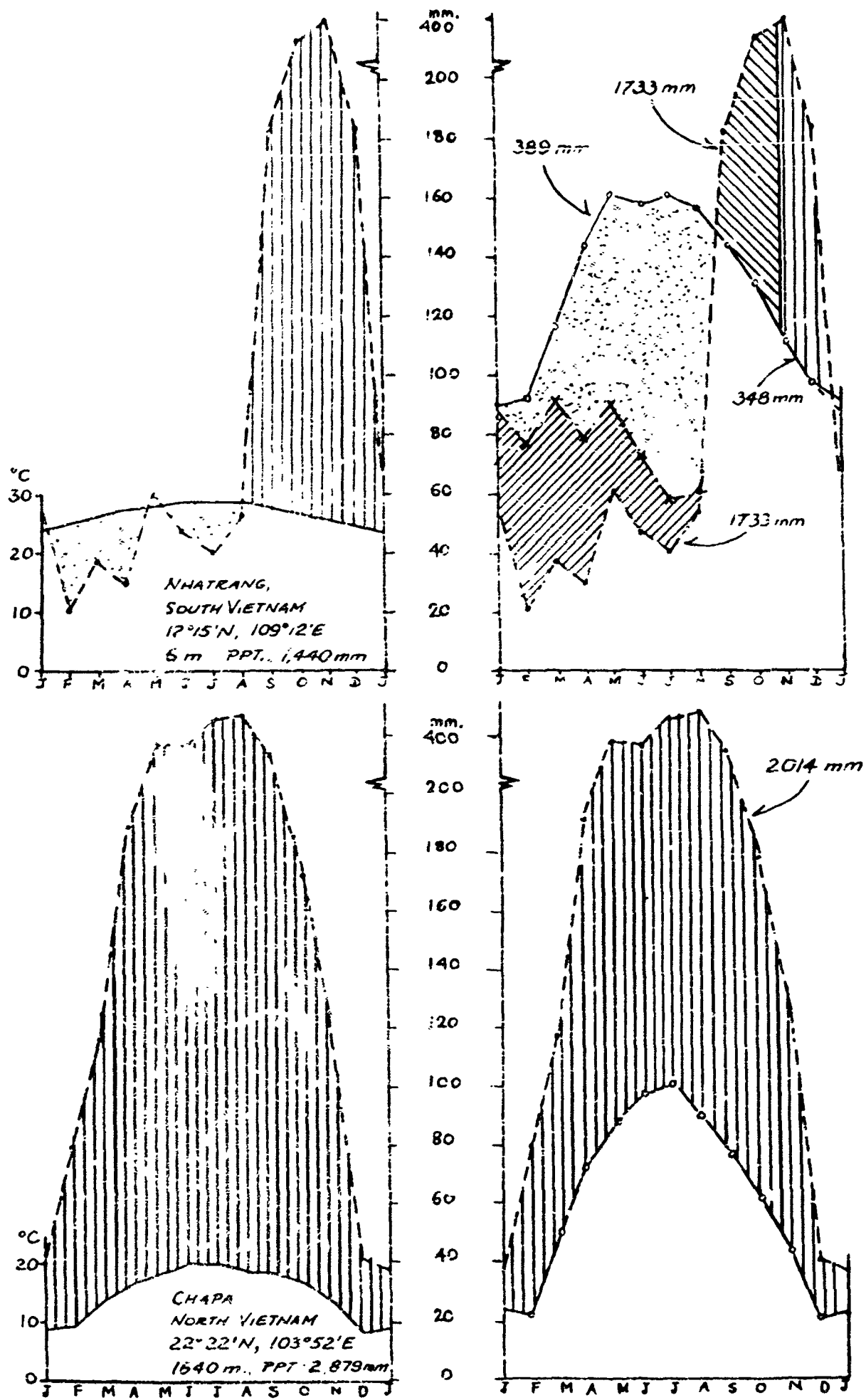


Fig. 13

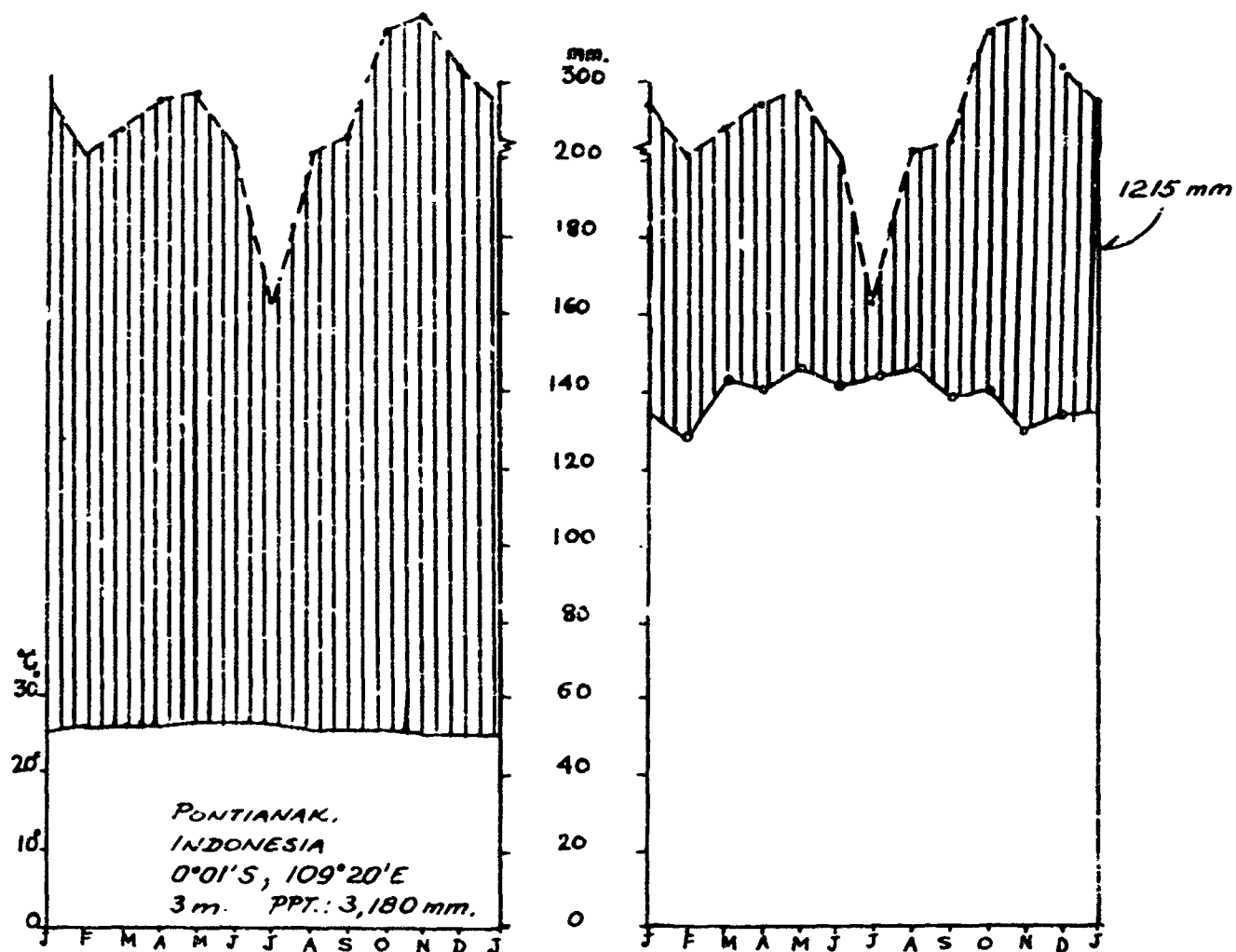
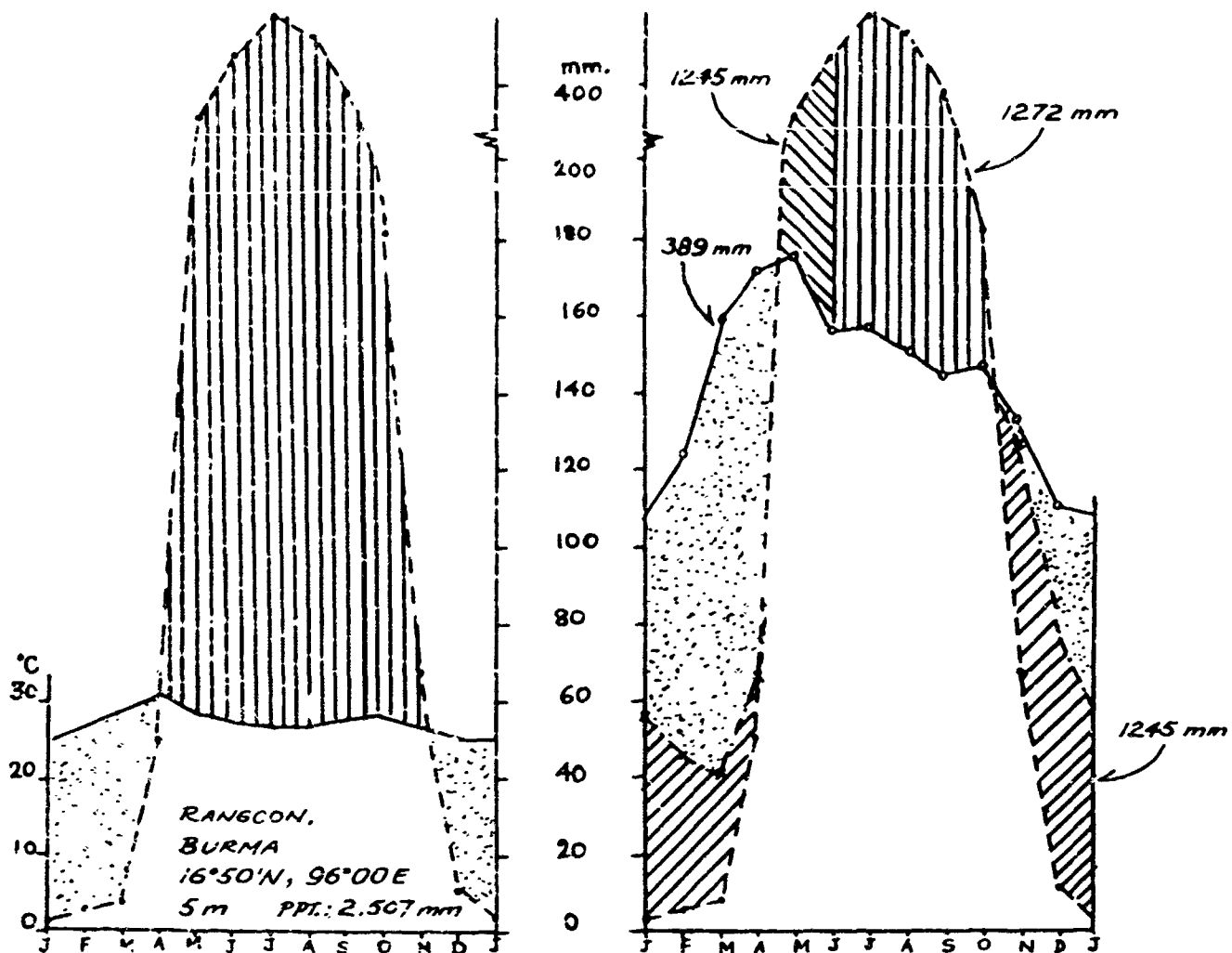
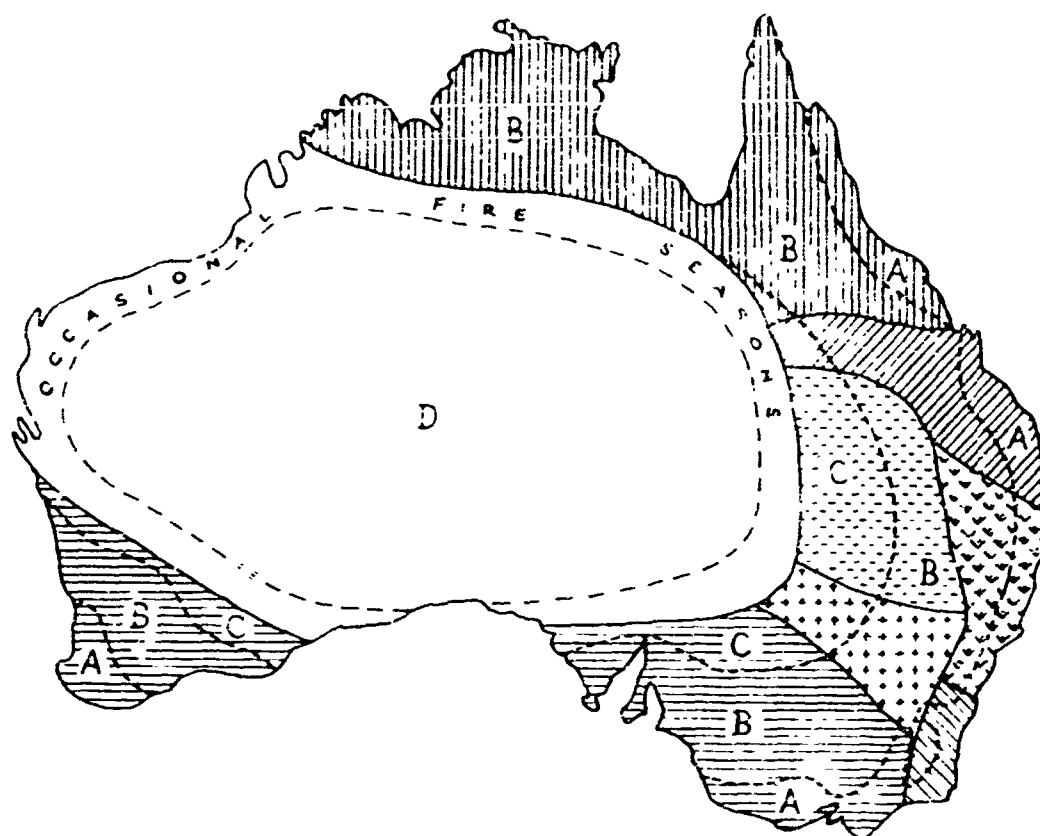


Fig. 14



MAP 1

DURATION OF FIRE SEASONS

ZONE	J	A	S	O	N	D	J	F	M	A	M	J
	●	●	●	●	0	-	-	-	-	-	0	●
	0	0	●	●	●	●	0	-	-	-	-	-
	-	0	0	●	●	●	●	0	-	-	-	-
	-	-	0	0	●	●	●	0	-	-	-	-
	-	-	-	0	●	●	●	●	0	-	-	-
	-	-	-	-	0	●	●	●	0	0	-	-
	-	-	-	-	0	●	●	●	●	0	-	-

Normal months of fire season ●
Occasional additional months 0
Fire occurrence very unusual -
Limits of fuel regions -----

FUEL REGIONS:

- A - Predominantly forest fuels with some open grasslands. Sufficient fuel for fires every season.
- B - Predominantly grass fuels but including large areas of savanna woodland. Sufficient fuel for fires in most seasons.
- C - Sufficient grass fuels in occasional seasons following above average rainfall.
- D - Arid. Insufficient fuel to support combustion in any season.

After McArthur, 1964

type of soil, from just a few millimeters to well over 300 mm. depth of water; and b) the rate of water loss from the vegetated soil surface depends on the existing soil moisture content. Thus, water is not equally available to the plant from field capacity to the wilting point. Some deficit will occur as soon as the soil moisture content drops below field capacity, and the water needs of plants will be increasingly difficult to meet as continued drying of the soil occurs." The data from which the climographs were prepared included computations for conditions of soil and plant cover which correspond to a soil moisture storage of 300 mm.

Three sets of curves are plotted on the climographs indicating the water balance at each station: potential evapotranspiration (PE), precipitation (P), and actual evapotranspiration (AE), which is the water loss from the soil. AE equals PE as long as soil moisture storage is at field capacity (300 mm. in this case), thus these curves frequently intersect as seasons progress. When soil moisture is less than field capacity, AE drops proportionally below PE. Water surplus occurs when P-PE values result after soil moisture is at full field capacity. Water deficit results whenever there is a P-AE value recorded.

b. Empirical Method of Bagnouls & Gaussen.--A simple empirical formula for distinguishing humid months from dry months, according to Bagnouls and Gaussen, is $P_{(mm)} \leq 2T_{(°C)}$, by which a period is dry if average precipitation recorded in millimeters is equal to or is less than twice the average temperature expressed in degrees centigrade. A graph so constructed in which the plotted vertical scales express this simple relationship, permits easy identification of the climatic dry period and its duration. The relationship of the two sets of curves is empirical and therefore there is no way to determine the intensity of the dry period. Thus, the stippled areas on the left-hand graphs do not have the same meaning as those showing the climatic water balance (see Figs. 8 through 14).

c. Evaluation of the Two Methods.--Thirteen stations were selected as a representative sample of major types of climates in each of the continental areas. Selected aspects of the graphs and the data from which they were drawn are arranged in Table 8 to facilitate comparison of the two methods. For each station and under the heading of site, the major type of natural vegetation is given.¹ The station climate is identified by letters of the Koeppen classification. Onset and duration of the climatic dry season is presented as well as an indication of the severity of the dry season. The latter is expressed as ecologically dry months (EDM), which are defined as months where recorded precipitation is 25 mm. or less (Phillips, 1965). (Table 8)

TABLE 8

ABILITY OF TWO CLIMATIC METHODS TO CHARACTERIZE A DRY SEASON

$P_{(mm)} \leq 2T_{(°C)}$ (Bagnouls and Gaussen)		Climatic Water Balance (Thornthwaite and Mather, 1955)
<u>AFRICA</u>		
<u>Ft. Lamy, Chad</u>		
Site:	Grass savanna and woody steppe (1) Subarid wooded savanna (2)	
Climate:	BSh No recorded precipitation: 4 mos.	
Dry Period:	Mid-Sept to June	Mid-Aug. to early July
Duration:	8 1/2 mos.	10 3/4 mos.
Severity:	EDM (ecologically dry months) = 7	Water deficit 1125 mm., or nearly twice annual precipitation

¹For stations in Africa under the heading of site, vegetation and bioclimate is presented adapted from Aubréville et al. (1959), and Phillips (1965). The vegetative descriptions of Aubréville and Phillips are indicated by the numbers (1) and (2) respectively. The major types of vegetation indicated for stations in Latin America were adapted from various individual maps contained in the map collection, Library of Congress, Washington, D.C. For those in Asia, Library of Congress maps were used as well as the study by Chambers (1961).

TABLE 8 (continued)

P (mm) \approx 2T (°C) (Bagnouls and Gaussen)		Climatic Water Balance (Thornthwaite and Mather, 1955)
<u>Elisabethville, Congo</u>		
Site:	Woodlands and savannas with abundant <u>Brachystegia</u> and <u>Julbernardia</u> (1) Tropical subhumid wooded savanna (2)	
Climate:	Cwa. No recorded precipitation: 3 mos.	
Dry Period:	April to Sept.	Mid March to Mid-Oct.
Duration:	5 mos.	7 mos.
Severity:	EDM = 5	Water deficit 170 mm.
<u>Salisbury, Southern Rhodesia</u>		
Site:	Woodlands and savannas with abundant <u>Brachystegia</u> and <u>Julbernardia</u> (1) Mild, subarid wooded savanna (2)	
Climate:	Cwa. No recorded precipitation: zero mos.	
Dry Period:	Late March to early Oct.	Late Feb. to Nov.
Duration:	6 1/2 mos.	8 1/4 mos.
Severity:	EDM = 6	Water deficit 128 mm.
<u>SOUTH AMERICA</u>		
<u>Aragua de Barcelona, Venezuela</u>		
Site:	Low tree and shrub savanna	
Climate:	Aw. No recorded precipitation: zero mos.	
Dry Period:	Dec. to mid- April	Mid-Sept. to early July
Duration:	4 1/2 mos.	8 3/4 mos.
Severity:	EDM = 1	Water deficit 546 mm.
<u>Choconta, Colombia</u>		
Site:	Temperate montane forest and dense shrub	
Climate:	Cwb. No recorded precipitation: zero mos.	
Dry Period:	Mid-Dec. to mid-Feb.	Late Nov. to March
Duration:	2 mos.	3 1/2 mos.
Severity:	EDM = 2	Water deficit 12 mm.
<u>Manaos, Amazonas, Brazil</u>		
Site:	Humid tropical forest (selva)	
Climate:	Am. No recorded precipitation: zero mos.	
Dry Period:	Mid July to Sept.	Mid May to late Oct.
Duration:	1 1/2 mos.	5 1/4 mos.
Severity:	EDM = zero	Water deficit 127 mm.

TABLE 8 (continued)

$P_{(mm)} \leq 2T_{(°C)}$ (Bagnouls and Gaussen)		Climatic Water Balance (Thornthwaite and Mather, 1955)
<u>Formosa, Minas Gerais, Brazil</u>		
Site:	Campo cerrado and semi-deciduous low forest	
Climate:	Aw. No recorded precipitation: zero mos.	
Dry Period:	Late April to Sept.	Mid-April to mid-Sept.
Duration:	4 1/4 mos.	5 mos.
Severity:	EDM = 4	Water deficit 92 mm.
<u>TROPICAL ASIA</u>		
<u>Rangoon, Burma</u>		
Site:	Humid tropical evergreen and deciduous forest	
Climate:	Am. No recorded precipitation: zero mos.	
Dry Period:	Early Nov. to April	Mid-Oct. to mid-April
Duration:	4 3/4 mos.	6 mos.
Severity:	EDM = 4	Water deficit 389 mm.
<u>Pontianak (Borneo), Indonesia</u>		
Site:	Humid tropical evergreen forest	
Climate:	Afi. No recorded precipitation: zero mos. No dry period	
		No dry period
<u>Nhatrang, South Vietnam</u>		
Site:	Semi-deciduous humid and subhumid forest	
Climate:	Aw. No recorded precipitation: zero mos.	
Dry Period:	Early Jan. to early August	Mid-Dec. to mid-August
Duration:	7 mos.	8 mos.
Severity:	EDM = 2	Water deficit 473 mm.
<u>Chapa, North Vietnam</u>		
Site:	Tropical and subtropical dense forest and shrub	
Climate:	Cwa. No recorded precipitation: zero mos. No dry period	
		No dry period

Several points are clearly shown by the table concerning the ability of the two climatic methods to identify and characterize a dry season. Both methods effectively determine the existence of a dry season from standard climatic data. As might be expected, certain differences in the two

methods occur for humid climates where abundant precipitation in one season nearly balances water losses by various physical processes during a period of lesser rainfall (see Figs. 9, Stanleyville, and 12, Manaus). The Thornthwaite method consistently indicated a longer, and therefore more severe dry period than did the method of Bagnouls and Gaussen. In most cases, the difference was one or two months, but for stations in South America, particularly, differences as great as three and four months occurred. If the tendency for the Thornthwaite method to identify a longer dry period is actually more realistic in terms of a period ecologically dry to vegetation and soil, then the difference in the two methods is significant. The rationale of the water balance method is not in question here, but rather to what extent the method correctly identifies vegetative dryness from climatic data meaningful to a study of combustibility. Until this can be done, the simple empirical equation of Bagnouls and Gaussen, and the definition of ecologically dry month (EDM) by Phillips, remain useful and are easily applied.

Few studies are available in which the complex interrelationships or microclimate, soil water conditions and natural vegetation have been studied in detail. Eden (1964), in reporting on the continuing research in the northern Rupununi Savanna, Guyana emphasizes the abrupt change that occurs in ecological conditions at the end of the rainy season. Whereas the relationships among rainfall, soil water conditions and runoff during the rainy season are direct, soil moisture content and water table levels are quickly affected at onset of the dry season. Basing his conclusions on detailed field instrument observations, Eden concluded that: 1) rates of potential evapotranspiration varied greatly from season to season: 2) measured rates of PE differed significantly from rates computed by the Thornthwaite method; and 3) that even though root depths to 180 cm.

for grasses were measured, the bioclimatic response to the dry season began shortly after cessation of rains (TABLE 9).

TABLE 9

MEAN DAILY POTENTIAL EVAPOTRANSPIRATION (PE),
ST. IGNATIUS, GUYANA 1963-64
(in millimeters)

Seasons	Pan evap. (mm.)	Lysimeter (mm.)	Atmometer evap. (mm.)
Rainy May 4 - Aug. 21	4.2	N/A	N/A
Early Dry Sept. - Dec.	7.3	7.1	7.6
Late Dry Jan. to Mar.	9.2	9.2	9.2

After Eden, 1964

Measured PE values at St. Ignatius (1963-64), when compared with Thornthwaite values, showed relatively close agreement for months of the rainy season. Monthly figures for mean daily PE during this period varied from 4.2 to 4.7 mm., and mean wind velocity measured at one-meter height above the ground was approximately 3 m.p.h. During the dry season (Sept. to Mar.), wind velocities varied from 4 to 8 m.p.h., the latter figure recorded in March, late in the dry season. Observed PE rose to a mean monthly total of 9.4 mm. per day for March, while computed PE values did not exceed 5.1 mm. per day for March, or for the period of record. Clearly, brisk winds sweeping over open grassland savanna increased the PE rate greatly. Actual evapotranspiration (AE) was much lower, being controlled in part by water supply. Values varied from 4 mm. per day in August near the end of the

rainy season, to less than 0.2 mm. per day in March late in the dry season. Eden stated that, at that time, ground water supplies were at 4 to 6 meters depth. Obviously, surface moisture in the form of sporadic showers and possibly dew formation was quickly returned to the atmosphere during the dry season. Thus, plant response depended on soil water holding capacity and ground water levels in relation to the root zones of the various types of vegetation.

For much of the tropics, climates are characterized by well-defined seasonality of rainfall. The role of climate is, therefore, dominant during rains, when soils and water tables are recharged. Actual evapotranspiration (AE) may be greater during the period of rains than during the following dry season because of plentiful surface moisture. Once the dry season begins, factors other than climate assume a more significant role in the water balance of an environment. Primarily because of the ease with which it can be applied, and considering the limitations of climatic methods to express clearly specific relationships to the incidence of fire, the method of Bagnouls and Gaussen was used in the preparation of the various maps appearing in Chapter V.

3. Aperiodic Factors Important to Fire.

The various factors that aperiodically combine to produce fire weather have long been identified and studied intensively. Any combination of wind, high temperature, and low atmospheric humidity preceded by a rainless period will quickly remove fuel moisture and increase combustibility. The severity of fire weather depends on a number of variables, including the persistence of desiccating conditions, or frequency of occurrence of brief dry spells. The characteristics and quantity of available fuel also contribute to the resulting fire danger.

The study of aperiodic atmospheric factors important to fire outbreak has as its primary purpose the identification of conditions associated with severe fire hazard in

order that reliable prediction of fire can be made and proper precautionary measures taken. Consequently, support for such studies frequently is initiated and encouraged by governmental agencies, both local and national, where concern for preservation of natural resources and protection of life and property commonly resides.

The various factors which contribute to dangerous combustibility of natural vegetation have been discussed (see Chapter II). Included here is a brief examination of certain meteorological phenomena known, or suspected, to be either conducive or inimical to the occurrence of fire.

a. Synoptic Weather Patterns.--The study of synoptic weather patterns associated with the leading up to widespread and severe fire has been limited to a few subtropical countries. However, narrative descriptions of conditions accompanying fire outbreaks in tropical climates leave little doubt that spells of weather occur in which very rapid desiccation of the natural environment takes place. Most of the tropics experience the effects of prevailing trade easterlies, ITC (Inter-tropical Convergence Zone), or monsoon circulation during the year. These planetary wind belts extend poleward to approximately 25 degrees of latitude in either hemisphere. The most characteristic and widespread feature of tradewind and monsoon circulation is the presence of surface air, usually moist, which is overlain by dry air that gently subsides. The boundary separating these quite different types of air is termed the tradewind inversion, which is most persistent and widespread areally over subtropical oceans.

The function and role of the tradewind inversion in the planetary atmospheric circulation is discussed by Riehl (1954). He notes that even for low latitudes, the low level moist air is not of great vertical thickness, and that dry air is found at upper levels. Thus the seasonal and aperiodic fluctuation in height of the tradewind inversion controls in part the presence and vertical thickness of the moist air

masses associated with the tropical westerlies.¹ Fluctuation in the movement of the zone of interaction between tropical westerlies and trade easterlies accounts for aperiodic, sporadic rains alternating with brief dry periods characteristic of seasonal transition in nearly all climates.

In Senegal, for example, dust carried on 20 m/sec. (45 mph.) NE winds, frequently heralds the end of the rainy season. The relative humidity may drop as low as 7 per cent, and the combination of winds, dry air and high temperature yellows grass in two days or less. Most countries bordering the Sahara experience similar conditions at the retreat of the ITC and the establishment of anti-cyclonic circulation. Similarly, Africa south of the equator experiences oscillations in the mean height of the inversion. Protracted dry spells and drought due to large scale fluctuations in mean wind flow occur in nearly all tropical climates, even those normally considered to be rainy. For example, drought has been reported in coastal Guyana, South America, over much of the Congo Basin, and even in parts of insular Southeast Asia.

Rainbird (1958), in discussing the various ways in which wind affects fire, draws attention to the importance of forecasting new cyclonic developments in existing troughs over Australia which may suddenly alter broad-scale air flow during critical periods. At the height of the monsoon season over India, rains may suddenly cease or be sharply reduced for periods lasting from a few days to a few weeks owing to variations in the southwest monsoon. Similarly, the

¹To many meteorologists, the tropical westerlies, ITC (Intertropical Convergence) and doldrums are one and the same phenomena differing only in regional characteristics and vertical structure. The ITC also is considered to be the zone of dynamic interaction of air masses comprising the tropical westerlies on the one hand and tradewind air on the other.

unpredictability of rainfall for northeast Brazil is believed due to fluctuations in the mean position of the ITC, vigor of subsiding air aloft, and variations in the pattern of air flow above the tradewind inversion.

Fire weather occurring during periods normally considered part of the rainy season has been reported in the Congo and in various countries in Latin America. Even during massive onshore flow of very moist air, which characterizes the rainy season in the Amazon Basin and West Africa, periods of a few days to a week, depending upon location, experience little or no rain even though skies are overcast and cloud ceilings are low. It appears that layers or zones of moist air alternating with relatively dry zones frequently exist in the highly stratified lower air. Gentle subsidence of the entire lower level would be sufficient to inhibit rain. Consequently, it is possible for primitive cultivators to simply stack the slash, and, because of the opening in the forest canopy, sufficient drying occurs to permit firing during a brief rainless spell even though there is no climatic dry season.

The problem of relating synoptic patterns to fire danger in the tropics is no less complicated and frustrating than it is for temperate latitudes. Currently, efforts consist mainly of applying criteria and techniques proved useful in middle latitudes and modifications to fit regional and local conditions (Foley, 1947; Larkins, 1958; Mizon, 1958; Rainbird, 1958; Schroeder and Countryman, 1960; Reifsnnyder, 1960, 1962; Stoddard, 1962). Most research has been limited to empirical considerations for various levels of fire hazard and danger rating systems. The criteria most often employed are temperature, relative humidity, wind speed and fuel state.

b. Local Topoclimatic Influences.--Atmospheric influences most critical to fire outbreak and behavior occur initially in the lower layers of air which is in intimate contact

with the physical landscape. Whereas correct analysis of a synoptic weather pattern may indicate potentially severe fire danger for a period over a broad area, the probability of fire depends on local conditions.

The surface wind is both the most obvious and in many ways the most important influence on fire behavior. As noted, oxygen supply to burning fuels, rate of fire spread and fire spotting are directed by winds. Variability of wind direction and velocity is very significant, and it is influenced greatly by topography. Unfortunately, little success has occurred to date in attempts to abstract and simplify wind patterns and yet retain a necessary degree of usefulness. Rainbird (1958), in his discussion on winds and fire during the dry season ascribes to the seabreeze far-reaching effects on fire behavior in Australian coastal areas. Inasmuch as the seabreeze is nearly ubiquitous in the tropics, its role as a suppressor of fire danger brought about by decreased temperatures and increased relative humidity should be noted. A seabreeze may, on the other hand, aggravate fires in progress due to sudden wind shift turning a fire front, or a brisk increase in wind velocity causing fire to escape out of control. Rainbird noted that occasional explosive convective buildup of fire in progress has occurred with the onset of a seabreeze. Of unknown importance is the stratification of the lower atmosphere accompanied by the sharp alteration of pre-seabreeze temperature and dew point lapse rates, once a seabreeze sets in.

The relation of the thermal structure of the lower air to atmospheric stability and potential convection over fire has long been recognized. There is, of course, a relationship between temperature lapse rates and the wind pattern. During typical fire weather, there is a strong diurnal fluctuation in the vertical temperature gradient that is reflected in surface wind structure. Intense solar heating of terrain during midday hours fosters development

of superadiabatic lapse rates isolating surface winds from upper air flow; air motion is relatively non-turbulent and controlled largely by topography.

Similarly, the diurnal variation in the state of atmospheric moisture near ground level is especially important to fire behavior in the tropics. In most of the tropics, the formation of morning dew and mists may extend well into, or entirely through the dry season. The amount of precipitable water in the lower atmosphere is surprisingly high over and in forest and woodland vegetation formations. Depending on nocturnal air drainage, heavy mists may occupy bottomlands for two to four hours after sunrise. Numerous references cite the hours of 1000 to 1500 local time as the most propitious for burning slash. The establishment of ground-level dew point inversions is known to quickly suppress fire danger because of the rapidity with which relatively fine fuel types respond to the presence of moisture. Numerous writers have mentioned that untended fires in forest and woodland clearings quickly dampen down after sunset not only because the encircling tree growth is effective in preventing fire spread, but also because of the sharp increase in relative humidity. References to fires observed at night are few even for those areas characterized by open grasslands.

Fire whirlwinds or fire storms are reported most frequently as occurring in extratropical areas. Greatly feared, fires of this type may suddenly develop in which convective buildup over the burning zone may rise to an altitude of more than 10 km. (33,000 feet). Numerous studies of fire whirlwinds have been made. While no two fires occur under the same conditions, it is known that when pronounced atmospheric instability develops through a deep layer, surface fire, largely controlled by topoclimatic conditions, can in minutes become a raging inferno. Frequently the change in atmospheric equilibrium accompanies frontal passage or the

movement into an area of an upper level disturbance. There is a notable scarcity of reports of fire whirlwinds in low latitudes. Severe fires of holocaust proportions have been reported in tropical Australia and south central Brazil. Although poor communications may account for the lack of reports of fire of this type, it should be noted that atmospheric conditions generally are not favorable. Strong wind shear at the tradewind inversion tends to shred cloud tops, while gentle subsidence prevailing in the dry upper air inhibits convection. However, fire cloud columns over extensive fires have been reported for many parts of Africa and Latin America. Cumulus and cumulonimbus produced by brush fires have been reported in Senegal, Sudan and Southern Rhodesia, as well as Matto Grosso, Brazil (Dessens, 1957; Tothill, 1948; Phillips, 1964).

The reciprocal of atmospheric influences on fire is fire-induced weather. Dessens in 1956-57 in a series of experiments attempted to form and build cumulus cloud by igniting brush fires in an effort to encourage rain during the dry season; first at Leopoldville and later at Bangui. Both localities experience the humid tropical climate of the Congo Basin. At Leopoldville, radiosonde observations indicate that on most days during the dry season, there is a three-layered structure in the atmosphere extending from the surface to 550 millibar pressure level. Warm and nearly saturated Atlantic Ocean air extends from the surface to 850 millibars, followed by a relatively dry layer with an inverted temperature lapse rate, above which occurs a deep and rather dry layer that is quasi-isothermal (Taljaard, 1955).

In one experiment Dessens reports the formation of cumulus that grew to a vertical development of 2.6 km. (8,600 feet) 6:22 minutes following ignition at 1603 hours of 30 m. tons of grass and brush which was spread over one hectare. Repeated experiments did not provide conclusive

proof that intense fire can induce cloud formation. There appeared little doubt based on films taken during the experiment, that pre-existing cumulus of modest vertical thickness grew to appreciable proportions over the fire area.

Fire whirlwinds and severe fire-induced weather do not appear to be of the same order of significance in low latitudes as in middle latitudes. The less frequent and abrupt alternation of synoptic weather patterns characteristic of the tropics, as well as the prevailing thermal and moisture stratification of the lower atmosphere during the dry season are important.

c. Determining Fire Hazard.--Criteria used for determining fire hazard in most tropical areas are modifications of those long developed and tested in temperate latitudes, usually the United States. In most cases, the systems are empirical tables or charts developed from experience gained largely by foresters and game conservators. The factors evaluated are temperature, relative humidity or dewpoint, wind speed and direction, gross characteristics of fuels and fuel moisture content, time since last rains, and seasonal weather patterns. These are assessed priorities or weights, or are transformed into index numbers. Various methods may be employed to arrive at an overall index of fire hazard. Generally, types of fuels and fuel conditions are highly important, so that multiple danger rating tables may be used, each table prepared for regional conditions, particularly, the dominant types of fuel present.

A useful aid in determining the occurrence and regional characteristics of fire danger is a fire season map. Climatic data, particularly seasonal rainfall, rainfall variability, temperature and dew point can be used to delimit seasons expected to be hazardous. These data, combined with qualitative data on the distribution of fuel types and quantities based on evaluation of vegetative formations, permit delimiting fire seasons. Past history

of fires could be incorporated to refine the map. Australia has produced such a map which is extremely useful, (see Map 1, p. 59), (McArthur, 1964). Use of hazard sticks or other techniques to quantitatively measure dryness in vegetation is limited largely to commercial forestry on protected tropical tree plantations, and to range management in parts of Africa and Australia. The qualitative character of fire hazard rating is due to the large number of variables and more importantly, the rapidity with which these variables change in time and space. For this reason, determining fire hazard is more of an art than a science, largely dependent on the degree to which local personnel are familiar with their area, and on experience derived from past fires.

4. Conclusions

Many specific needs for fire weather research have been expressed (Keetch, 1959; Reifsnyder, 1962; Whittingham, 1965; and Wilson, 1958a, 1958b). Some of the needs include: 1) development of procedures for predicting important weather conditions that have a severe impact on fire danger; 2) development of procedures for fine scale measurement and analysis of weather elements in mountainous terrain; 3) development of methods and techniques for interpreting long range synoptic forecasts in terms of local fireweather conditions; and 4) development of techniques for the use of data located at forecast centers in the preparation of essential guidance material for use by officers and workers of small agencies directly connected in various ways with fire

C. Fire and Natural Vegetation

The effects of fire on the floristic and gross physiognomic characteristics of tropical vegetation are both catastrophic and subtle. Clearing of forest and woodland by ax and fire abruptly changes the microclimate and

biological environment. Regeneration in cleared areas is rapid, but plant succession on abandoned plots depends on a host of factors including the frequency and intensity of fire. Repeated fire in forests initiate subtle changes in the environment. Fire-sensitive species are gradually eliminated and the floristic composition of the forest becomes impoverished. Degradation of the ecological environment inevitably leads to the establishment of plant communities adapted to physiologically drier conditions. Degradation of forest and woodland also proceeds from an initial state of low potential combustibility to varying degrees of greater combustibility.

Similarly, fires' effects on the various types of savanna produce temporary and lasting change. The familiar scene of blackened earth, scorched tree and brush, and carbonized fragments littering the surface suggests total destruction. However, many plants are fire-resistant and respond quickly following fire with new growth. Repeated burning, however, attacks even the most fire-resistant species, so that gradual elimination of trees and brush occurs resulting in a landscape largely characterized by grasses, low herbaceous plants and fire-deformed shrubs.

1. Major Types of Tropical Vegetation

Nearly 15 million sq. km. (5.8 million sq. mi.) and 17.4 million sq. km. (6.7 million sq. mi.) of the earth's surface support tropical forests and savannas respectively. Numerous detailed studies identify, classify, and describe natural vegetation, largely floristically and physiognomically. Although studies of small areas may indicate dominant ecological relationships, no meaningful generalizations can be applied to broad areas. This is not surprising, considering the complexities involved in determining botanically and otherwise, the diverse character of tropical vegetation. There is an almost infinite number of variables contributing to specific aspects of site,

location, floristic composition, gross physiognomic characteristics, and dominant ecological relationships. Poore (1963) in discussing problems in the classification of tropical rainforest noted that the "technical problems of description and identification are so great, and so little is known of the effects of climate, soil and other living organisms on the vegetation, that little progress has been made." Even selecting representative areas in tropical tall forest is difficult because dominant species so necessary to aid classification are few. Knowledge of the Malayan rainforest is more advanced than of many other equatorial regions, but even there basic data on its structure and pattern are inadequate. Poore concludes that it is still too early to develop methods that are both satisfactory and economical to classify forest types and to investigate their relation to habitat.

The problem is no less complex for identifying and describing savanna vegetation. The literature is replete with descriptive names used to identify tropical grass and woodlands. A tabular presentation of descriptive terms for the vegetation types classified or mapped as savanna vegetation as well as a table indicating name-equivalents according to classifications of savanna vegetation appears as Appendix II (Hills, 1965). An extremely useful map, Major Bioclimatic Regions of Africa South of the Sahara, by Phillips (1965) combines floristic and physiognomic characteristics of natural vegetation with selected qualitative ecological values of climate and geographical location. Striking similarities exist between Phillips' map showing the distribution of his bioclimatic regions and the Vegetation Map of Africa, by Aubréville, et al. (1959), although each was produced independently. The categories appearing on these maps were ideal for relating fire and natural vegetation. Consequently, the categories were adapted for the preparation of maps showing

the distribution of fire in the tropics and the relation of burning to climate and natural vegetation (see Chapter V).

To facilitate examination of a complex subject, the effects of fire on natural vegetation are discussed primarily on the basis of overall biological environments, including microclimate, major physiognomic characteristics of vegetation, and general characteristics of degradation and regeneration of the vegetation. Consequently, no attempt is made to analyze each of the types of vegetation appearing on the maps in Chapter V. Rather, the collective characteristics of vegetation and environment are grouped into the following three categories: 1) low elevation, humid tall forest and rainforest, and medium elevation, humid montane forest; 2) forest-savanna mosaic, that is, tall degraded forest coexisting in various proportions with savanna; and 3) wooded savanna and open grassland savanna. In the last category the effects of fire on grasses and woody growths are treated separately even though they appear together in a wide variety of vegetative landscapes. These forests are associated with tropical rainy (Af) and tropical monsoon (Am) climates, and there is abundant moisture in the ground to carry the humid forest through an ecologically dry period varying from one to two months. The microclimate is characterized by high humidity in which relative humidities are rarely below 75 per cent, and there is virtually no wind. Measurements of the effect of the forest on precipitation indicates that perhaps as much as 20 per cent is retained in the canopy and is lost by evaporation. The general distribution of that which passes downward is approximated by experiments conducted in the tropical rainforest of Brazil (Freise, 1936).

TABLE 10

PERCENTAGE DISTRIBUTION OF RAINFALL IN THE VEGETATION ZONE,
TROPICAL RAINFOREST, BRAZIL,¹
(per cent of total rainfall)¹

Caught and evaporated in forest canopy ---	20			
Caught in raingauge ---	33			
Rain running down tree trunks ---	<u>46</u>	Evaporated on trunk surface ---	9	
		Absorbed by tree bark ---	9	
		Reaching base of tree ---	<u>28</u>	Reached water table ---
				7
				Absorbed by roots --- <u>21</u>
Totals	96		46	28

¹Total rainfall recorded and the period of observation are not known.

After Freise, 1936.

2. Humid, Tall Forests and Montane Forests

a. Characteristics of the Environment.--A variety of forests are found in equatorial latitudes in climates experiencing 1600 to more than 6000 mm. of rainfall annually with no definite dry or drier season. Tropical rainforest, humid monsoon forest, mixed tropical evergreen forest, semi-evergreen forest and humid semi-deciduous forest are only a few among the confusing array of terms applied to forests noted for their floristic and physiognomic diversity. In an effort to avoid the problem of the ratio of evergreen to deciduous species occurring in a forest, the terms mixed evergreen and semi-evergreen have not been used. The term humid semi-deciduous forest has been applied to all forest types in which certain species respond to dry or drier

periods by shedding leaves, but many tree species are also broadleaf evergreen. The term is also restricted to humid forests located below 600 m. (2,000 feet) elevation.

The floristic and physiognomic characteristics of these types of forest differ greatly from each other and differ within each type in different parts of the tropics. Generally, these forests are characterized by dense stands that vary in height from 18 to 60 m. (60 to 200 feet) or more, with few dominant species. A three-tiered leaf canopy frequently is present, and undergrowth is limited because of the interlocking leaf canopies. Horizontal visibility in a mature forest is 60 to 100 feet. Fairly abundant raw organic matter litters the forest floor, and the moist soil possesses more incorporated organic matter than as found in soils under dry semi-deciduous forest.

Humid montane forests may be broadleaf or needle leaf, evergreen or semi-deciduous occurring at moderate elevations (600 to 2100 m.; 2000 to 7000 feet), in plateau uplands and mountainous areas. Latitudinal location, elevation and exposure to prevailing winds are important environmental factors in determining the type of forest. Moderate to heavy precipitation may occur due to orographic uplift of moist air. Except for persistent cloud zones, the cool temperatures recorded are less a factor than one may suppose, because intense solar radiation that is typical of low latitudes. On the other hand a modest increase in relief appears to be sufficient to cause differences between rainforest and submontane forest. This transitional type of forest is rarely more than 25 m. (82 feet) tall and commonly has two stratified layers. At higher elevations, the true montane forest is only 10 to 15 m. (33 to 50 feet) high, and usually a single stratum of trees is present. A modest undergrowth is commonly present in both types of forest even though canopies are touching or closed. Stands are dense, and if

undisturbed, the microclimate and biological environment is too humid to sustain fire.

In East Africa, Central and Caribbean America and Mexico, stands of conifers, notably pine and cedar, clothe upper mountain slopes. In Africa, pines are exotic species planted in forest reserves. Species of pine commonly grown are Pinus radiata, P. elliotti and P. patula. These commercial species are protected from fire by modern methods. However, fires do sweep into forest plantations from adjacent areas. In Mexico, Central America and Hispaniola, pines and cedars occur at elevations higher than 1,000 meters (3,300 feet). The presence of pure stands of Pinus pseudostrobus in Guatemala is a positive indication of past burning.

b. Impact of Fire.--The impact of fire in humid, broadleaf montane and tall tropical forests is associated with clearing by shifting cultivators preparatory to planting crops. Practices employing the use of fire vary widely among various peoples: hence, the effect of fire on humid forests is directly related to cultural traditions (see Chapter IV). From a botanical and ecological viewpoint, once a clearing is made an abrupt change occurs in the environment. Trees are felled, girdled, or both, and the slash piled over a portion of land cleared to produce fertilizing ash when burnt. Even for tropical areas experiencing no well-defined drier season, the piled slash dries sufficiently in a short period of time to permit burning. Because the quantity of fuel per unit area is large, fires are intense. A successful burn is one in which all but the larger logs are consumed. Surface litter plus most of the soil humus is reduced to ash (see Chapter IV). A less intense burn results in rapid reclamation of the plot by seeds and bushy growths, because weeds and rhizomes are not killed.

c. Types of Regeneration.--Various types of vegetation reclaim abandoned clearings. One sequence is the establishment of a dense growth of light-loving brush and trees. These species, which are suppressed in the mature surrounding forest, quickly respond to the opening in the leaf canopy made by fire. In fact, abandonment of cultivated plots is due as much to encroachment of brush and weeds as it is to soil exhaustion. First year growth may be more than 4 m. (13 feet) tall and so dense that movement on foot is virtually impossible. Visibility is limited to a foot or two (see PLATE 5, p.88). The initial rank growth is gradually replaced by the less readily disseminated tree species, and a process of succession is begun which results in the re-establishment of a new forest.

In many parts of the tropics, grasses not trees occupy abandoned clearings and form a dense surface cover which preserves the forest opening. In certain parts of Africa, India and Southeast Asia, elephant grass (Pennisetum spp.) is quickly established, especially if soils are relatively fertile. On exhausted or badly eroded soils, perennial coarse grasses such as spear grass (Imperata spp.) and Sorghum spontaneum are found. These latter grasses are so widespread that they are known by many regional names. In Sumatra, Vietnam and other parts of Southeast Asia, Imperata and its associates are termed lalang; in Malaysia, alang-alang; and in the Philippine Islands, cogon. These grasses are also widely distributed in tropical Africa and America. Depending on frequency of fire and environmental conditions, the grass cover varies in height from 1 to 2 m. (3 to 6 feet). Imperata spp. will burn even when green and its fire is intense. In Africa north of the Congo Basin, in plots protected from fire, Imperata is gradually replaced by other coarse perennial grasses, such as Andropogon spp.

Numerous clearings support jungle-like vegetation consisting of bamboos and a few quick-growing, soft-wooded

trees. Bamboo represents a successional stage in forest regeneration in much of tropical Asia. Parts of Burma, Thailand, North and South Vietnam and India possess extensive areas of bamboo thicket or forest. Stamp (1925) noted seven different types of bamboo vegetation in Burma, and considered the prevalence of bamboo to be due to widespread deforestation. Burmese forests frequently have a bamboo understory, and even though clearing and burning of the forest takes place, enough bamboo sprouts apparently survive to quickly reclaim abandoned clearings. In his study of Tim and Kamuk people of northeastern Thailand, Credner (1935) noted that weeds reclaimed a clearing in the second year which were quickly succeeded by bamboo. The bamboo, however, did not give way to small trees until 10 years or more had passed. The transformation of humid evergreen forests located in the Chittagong and Arakan regions (Burma and East Pakistan) to bamboo forests by widespread clearing for shifting cultivation was the object of deep concern by Champion (1929). In both North and South Vietnam, lower hill lands and plains are in bamboo attesting to clearing of forest, while its persistence is due to its utilization as construction material. In areas where soil drainage is poor, bamboo and elephant grass occur together producing dense stands in which horizontal visibility is less than 2 m. (6 feet).

Forest clearings distant from grass seed sources more frequently revert to successional stages leading to forest than those located near savannas. Where fire has fed on a fairly deep surface organic layer, the soil may have undergone significant change in bulk density, water storage capacity and aeration. Presumably the fire-altered soil now exposed to the weather is unable to immediately support tree seeds wafted into the clearing. Budowski (1956), on the other hand, states that there is "no evidence to believe that in tropical regions a soil may become too poor to support forest growth."

Cultural factors also are significant to rates of regeneration on cleared land as well as to the type of plant succession. Closely associated with soil degradation are the cultural practices which determine selection of site, the intensity of cultivation, and the length of time the plot is used before abandonment. Another important factor is the length of the forest-fallow period which is related to population pressure on the land and the type of shifting agriculture practiced (see Chapter IV).

A very useful set of generalizations for secondary succession in humid forest environments was derived from intensive study of 16 plots in Costa Rica and Western Panama. All were located in areas with temperatures ranging from 23.5°C-25.5°C. (74°F-78°F), annual rainfall varying from 2000-4000 mm. (80-160 inches) (Budowski, 1962). Each of the plots illustrated different successional seral stages in forest regrowth. Relatively good knowledge of past disturbances by man was available. Techniques used in making the study followed essentially the recommendations by Richards, Tansley and Watt (1940). The generalizations derived from the study are set forth below:

- 1) The floristic composition of pioneer communities is limited to a few species of wide natural distribution. There is little variation in the species represented in spite of different soil or climatic conditions.

- 2) The number of strata in a community is highly indicative of its successional status. Few and well-defined strata reveal an early seral stage whereas several strata, difficult to separate, reveal an advanced stage of succession.

- 3) The absence of large stem diameters is a characteristic of early stages of succession.

- 4) A dense undergrowth is characteristic of very early stages of development but not advanced stages of the climax.

- 5) The shape of the upper crowns is highly indicative. Early stages display uniform, thin light-green crowns. Older stages display many variations in crown forms and a darker green color.

6) Intolerance of the dominant species is characteristic of early stages and decreases towards the climax where most of the dominants are tolerant.

7) The evenaged condition is characteristic in early successional stages. There is a gradual change to an unevenaged condition with advance towards the climax.

8) Early pioneer species characteristically have small seeds that are dispersed by wind, birds and bats. Old secondary or climax species mostly have large fruits and seeds, many of which are dispersed by gravity.

9) Deciduousness is characteristic of many of the dominants in communities of intermediate status between the very early and the very advanced seral stages.

10) Seeds of early pioneer species may remain dormant in the forest soil until favorable conditions such as clearing and fire trigger their development.

11) Regeneration of the dominants is common in advanced stages but infrequent or absent in early pioneer stages.

12) Diameter and height growth is very rapid in early pioneer stages.

13) Rapid reestablishment of an advanced stage of the original forest is favored by proximity of such a forest to the disturbed area; redevelopment of the original forest is more rapid in small clearings than in large ones.

14) The presence of dominants having a very short life span is highly indicative of an early stage of succession.

15) The presence of a large proportion of species with leaves of the macrophyll size class, is indicative of an early pioneer stage. Climax species mostly have mesophyll leaves.

16) The hardness and weight of wood is highly indicative of successional position. The wood of trees representing early stages is soft and light whereas in species characteristic of advanced stages the wood is hard and heavy.

17) Climbers are highly indicative. In early stages of successional development, there are few species but many individuals and they are mostly herbaceous, often forming a tangle. In advanced stages of succession, they are large and woody with many species, but are not abundant.

18) An increasing number of species and variety in life forms of epiphytes is characteristic of progressive development towards the climax.

19) Certain species are highly indicative of the successional status of the community. Some can be correlated with past practices, notably exhaustive agricultural or fires. Others, notably palms, are indicative of long undisturbed conditions.

20) On lateritic soils the presence of a community with dominants typical of habitats much drier than the rainfall would indicate for the region, points to past soil degradation, mainly compaction through extensive use of fire.

c. Potential Combustibility.--A fundamental relationship between vegetation and fire is the role vegetation plays as a fuel in which widely different fuel types and quantities are spatially arranged in one or more levels. Inflammability of fuels depends not only on the composite physical character of the matrix, but also on the response of dominant species to increasing desiccation (see Chapter II). Potential combustibility is conceived to be a broad term encompassing that range of phenomena which contribute to the ability of an ecological environment to sustain fire without cutting and stacking fuels.

Potential combustibility in tropical rainforest is exceptionally low. The combination of high humidity beneath the upper canopy, absence of wind, and high moisture content of the forest litter produce an environment inimical to fire from natural causes. Consequently, fires started by lightning are rarely reported, even though low latitudes experience a high frequency of thunderstorms. The difficulties encountered by foresters deliberately igniting fuels in the Malayan rainforest illustrates the non-combustible character of humid forests (see Chapter IV, sec. B 3).

Fires can be started by shifting cultivators only because of the complete change that takes place in the micro-climatic and biological environment. Very intense fires fed by piled slash that has dried only three days have been observed near Leopoldville (Phillips, 1965). The forest surrounding a burning plot, however, is an effective barrier

to fire spread. Consequently, fires in clearings are usually untended at night. The sharp increase in atmospheric moisture beginning near sunset quickly dampens smoldering logs and embers.

Potential combustibility in humid broadleaf montane forests is very difficult to assess because of the influences of topography upon climate and other characteristics of the environment. The montane forest is composed of many types which, depending on terrain, climate and soils, change abruptly from one type to another within short distances. Lowest potential combustibility would occur in forests so located as to be persistently in cloud and rain caused by exposure to prevailing orographic uplift of moist air masses. Moderate to heavy precipitation in montane forest is offset by rapid surface runoff on steep slopes, high winds and the chimney effect of fire moving upslope. Although undisturbed forests are relatively impossible to ignite, areas that have been cleared slowly return to the original type of cover. Loss of exposed soil may prohibit tree growth so that the brush, regenerating on such area, represents an environment having a higher potential combustibility.

Potential combustibility in coniferous montane forests is high, particularly since they occur in areas experiencing a climatic dry season. In commercial pine forests, burning is often employed as a tool to reduce fuel accumulation to lower fire hazard. Mature pines are relatively fire resistant if flames do not seriously scorch tree crowns. Seedlings are more susceptible to fire. Precautionary measures employed to suppress fire in commercial forests are modern in terms of techniques and equipment (see Chapter IV).

3. Forest-Savanna Mosaic

a. Characteristics of the Environment.--Centuries of clearing and burning in humid tropical forests have pro-

duced extensive geographic areas where forest and savanna coexist in complex patterns (see maps, Chapter V). The term forest-savanna mosaic is essentially morphological and designates the replacement of forest by seral stages of various types of savanna appearing in a dominantly forested landscape (Aubréville et al., 1959). The mosaic pattern occurs in degraded rainforest and montane forest located in humid climates where ecologically dry period rarely exceeds two months (see PLATE 6, p. 88).

In the tropical monsoon (Am) and, wet and dry (Aw) climates where the well-defined dry season is short, tall forests co-mingle with less tall, mostly deciduous forests. These forests occupy upland sites, whereas the more humid types are found along rivers, in deep ravines and other protected areas. The drier forest is multistoried with leaf canopies that are closed or touching. Undergrowth, if present, is dense brush; grass is not present in an undisturbed forest. The effects of fire upon this more open type of forest has been severe. After clearing, tall grasses reclaim the land. Retreat of the forest has been fairly rapid in many parts of the tropics, notably in south-central Africa, where forest relics appear as isolated remnants surrounded by open savanna (see PLATE 7, p. 89).

An infinite number of gradations occur in the ratio of forest to savanna in the mosaic pattern and no one term is adequate. The term derived savanna with its genetic connotation, also appears in the literature and refers to the forest-savanna vegetation complex (Keay, 1959; Phillips, 1965). This term applies especially well to the vegetation of Africa, where many excellent studies have documented the effects of fire on forest vegetation. Numerous experimental studies also indicate that when protection from fire and human activities is provided, grasses of the forest-savanna mosaic are quickly invaded by brush as a pioneer stage leading to forest (Aubréville, 1953; Richards, 1952; Budowski, 1962; Fuson, 1963; Denevan, 1965).



PLATE 5: First year regenerated growth behind field worker. Maize crop on second year cycle of shifting cultivation in rainforest; Lake Izabal, northern Guatemala (Photo by H. Popenoe).



PLATE 6: Brush and grass opening made by ax and maintained by fire in tropical rainforest located just north of the equator in the Republic of Congo (Brazzaville), (Photo by J. F. V. Phillips).



PLATE 7: Relict subtropical, humid, montane forest, East Criquealand, South Africa. Forest retreat due to axe, browsing and fire (Photo by J. F. V. Phillips).



PLATE 8: Abrupt forest-savanna boundary coinciding with physiographic border between lowland and mountain slopes. Fire has penetrated rugged hills in background. Northern Rupununi, Guyana (Photo by T. L. Hills).

b. The Forest-Savanna Boundary.--In order to identify and clarify the processes by which forests degrade, a number of studies have explored the forest-savanna boundary.¹ Basically two types of boundaries with many variants have been observed. In many areas a zone of varying width containing low trees and brush with a grass ground cover separates more open savanna from forest. Elsewhere, the boundary is abrupt in which the change from grassland to forest may take place within a distance of four meter, (13 feet) (PLATE 8). It is important to understand the action of fire in these two boundary situations, particularly with respect to the significance of changes that occur in ecological conditions in forest. Until these are clarified, constructive use of fire in grassland and forest management suffers.

In all probability, degradation and retreat of a forest boundary depends on frequent occurrence of fire attacking the forest edge from established savannas. Since the attack is on dense. rainforest, montane forest, or tall deciduous forest characterized by a close or nearly closed canopy. potential combustibility in these types of forest is low.² A basic question, therefore, is how degradation of an essentially non-combustible forest is initiated, and once begun, how it progresses.

¹The boundary between tropical forest and savanna grassland was the focus of an international symposium to which invited authorities from many countries presented papers which are to appear in a single volume I.G.U. Symposium on the Ecology of the Savanna-Forest Boundary, Venezuela, May 1964.

²The various types of subhumid and semiarid, semi-deciduous and deciduous forests which are significant components of savanna landscapes are not being considered.

In traversing the deep linear filaments of savanna invading the Gabon forest, Aubréville (1949) found that brush fires from the savanna actually penetrated many meters into the tall forest in some places. Where fire invaded the forest the farthest distance, it had fed on accumulated litter and a relatively deep humus layer. Fire did little direct damage to the lower tree trunks, but certain fire-sensitive species were killed by fire attacking the upper portions of their roots. Dead trees quickly succumbed to attack by insects and microbial activity and were easily toppled by wind. That humus fires are possible in dense humid forest and can be very intense, is made clear by the account of the disastrous fire in the virgin state forest, Vohibe-Autocha, Madagascar, November 1955 (Vignal, 1956). A surface fire, ignited for purposes of clearing during a period of extreme drought, became uncontrollable, destroying some 1,500 hectares (3,750 acres) of primary forest. The fire spread in the deep surface litter extending downward to a depth of 5 to 10 cm. below the surface. Mature trees were killed at upper root level and rapidly felled by winds and their own weight. The humus layer was completely destroyed leaving a mixture of sand and ashes overlying the lower horizon. It is doubtful that the original forest cover will ever be reestablished.

Puri (1960) in his two-volume comprehensive survey of vegetation on the subcontinent of India unequivocally states that savannas are derived from degraded forests. Fire protection in forests possessing commercial value results in heavy stands often characterized by dense understories. Consequently, such protected forests experience fire only in relation to forest management. Elsewhere, overgrazing and annual burning, collection of wood for fuel and construction material, have reduced forests to woodland savannas. Puri states that the presence of big trees, such as Shorea robusta, Adina cordifolia, or Lagerstroemia parviflora, in savannas indicate the existence of previous high forest.

The effects of fire on plant communities in northern Australia indicate that burning has a long history. Where annual precipitation exceeds 889 mm. (35 inches), the land in the north is fired annually. Southward toward the interior desert, the accumulation of fuels is slow so that fierce fires occur perhaps once in 10 years. Fires set by aborigines are for hunting, food gathering, and to enable easy movement from place to place. Indiscriminate burning, however, is not practiced because of the scarcity of food supply for the nomads. The overall effect of centuries of burning both by aborigines and later by European settlers, has been to produce a vegetation landscape in which many if not most vegetative formations have been altered by fire (Stocker, n.d.). Along the northern coast occur patches of semi-deciduous, tall forest densely festooned with vine. These remnants are located in areas possessing abundant soil moisture and high ground water tables (Specht, 1958). Stocker, after examining many of these relic communities, concluded that the availability of soil and ground water determined only the total height and complexity of the formation, and that existing rainfall was adequate to support this type of vegetation on many soils. Fire is the dominant agent restricting the area of forest. In many forest patches there was no significant penetration of fire into the undisturbed forest. The implication is that the boundary between relic forest and wooded savanna may well have been abrupt.

Fire is known to be a significant agent in maintaining sharp dividing lines between forest and savanna vegetation, but it is not clear how the boundary reaches dynamic equilibrium. (PLATE 9). Study of the northern Rupununi savanna, Guyana (British Guiana) indicates that the main forest vegetation is found on hills and mountains along the physiographic margin of the savanna which occupies a late Tertiary lowland (Eden, 1964). Locally, the savanna



PLATE 9: Savanna abutting stony slopes clothed in dry, semi-deciduous forest. Boundary width is less than 4 meters and is maintained by fire. Northern Rupununi, Guyana (Photo by T. L. Hills).



PLATE 10: A few meters distance into the dry semi-deciduous forest (see Plate 9). Stoniness and lack of surface litter may account for inability of fire to penetrate forest from the savanna. Northern Rupununi, Guyana (Photo by T. L. Hills).

has transgressed into the hills, but there is a general coincidence of semi-deciduous forest grading into rain-forest at higher elevations on elevated terrain, and savanna with bush islands in the lowland (PLATE 8, p 89). Bush islands and galeria forest in the savanna, according to Eden, are distinct formations both floristically and physiognomically, and differ from the main forest associations. Soil water and ground water levels in the savanna differ markedly from those of the uplands. Annual fires in the savanna may well contribute to maintaining the sharpness of the boundary, but it appears that the respective environments are hostile to invasion by vegetation across the forest-savanna boundary. Savanna tree species are intolerant of shaded conditions that occur in the forest. Conversely, the forest trees are fire-susceptible, particularly in the sapling stage, and therefore, would not regenerate easily in the savanna. Furthermore, the abrupt change in fuel types and quantity across the vegetation boundary results in radical change in potential combustibility (PLATE 10).

Among the many physical aspects investigated in the forest-savanna mosaic, there is, at present, no clear understanding of the relative significance of the many differences noted in the two types of environment. Transitional boundaries may well occur where no great differences are present in geologic strata, soils, and topographic relief. In such cases, repeated burning will first selectively kill fire sensitive tree species at the forest edge. The dense upper canopy is thinned, permitting an increase in insolation reaching the ground which promotes rapid growth in the understory. Consequently there is a sharp increase in the quantity of finer-textured fuels which then respond quickly to onset of dry conditions. The more open nature of the forest also permits soils to dry out more rapidly, and there may be a fall in the local water table. Each new fire season fire penetrates more deeply into the forest. Adlard, (1961)

states that in Southern Rhodesia, Katanga and Angola there have been reported lanes of fire-tolerant trees with a grass understory entering humid montane forest communities. The lanes into the forest are parallel to prevailing winds of the dry season.

Conversely, abrupt forest-savanna boundaries appear to be associated with strongly contrasting ecological environments. The influence of geologic strata, topographic relief, climatic dry season, geomorphic processes leading to formation of laterite crusts, and soil-water relationships, singly or in combination, have been advanced as causal factors able to maintain forest and savanna environments with abrupt boundaries. The role of fire as a maintaining factor is relatively clear. Regeneration of grass, and particularly, wooded savanna is well-documented in many parts of the tropics. It is possible that even where the forest-savanna boundary is sharp, absence of fire results in forest invading a physiographically distinctive savanna environment. Such may be the case in the sparsely occupied southern Rupununi savanna (Waddell, 1963).

c. Potential Combustibility.--The forest-savanna mosaic has many characteristics which favor high potential combustibility. Fuel quantities are large and arranged at different levels so that the entire fuel complex has a large surface exposure. The tropical monsoon (Am), wetter margins of the tropical wet and dry (Aw), and drier margins of the tropical rainy (Af) climates all experience a drier or dry period extending from one to two or three months. Vegetative response to the ecologically dry season is a varying proportion of deciduous trees in evergreen forest communities, and the rapid desiccation of grass and brush vegetation of open areas. The tall, perennial grasses become woody as they mature and respond quickly to drier conditions. Thus a fine, homogeneous type fuel is present, and when ignited burns fiercely.

Although certain aspects of the forest-savanna mosaic suggest high potential combustibility, other aspects reduce the ability of fire to effect widespread devastation. The pattern of vegetation is one of disparate elements each possessing distinctive microclimate and biological environments. While annual burning may occur in savanna areas, the forest acts as a barrier to fire. Consequently, the overall combustibility of this type of vegetation landscape depends on the ratio of forest to savanna. Since the mosaic pattern is derived from degradation of humid tropical forests, it should be remembered, that clearing of the forest is the dominant factor, and fire is essentially a tool in the modification of the landscape.

4. Wooded and Open Savannas

a. Characteristics of the Environment.--Tropical savannas are very widespread and are found in a wide range of physical environment. Savannas are found along coasts and at elevations above 1000 m. (3300 feet). Certain savannas may owe their origin to edaphic, biotic, geologic or some other condition. It appears unlikely that climate alone is a factor in the distribution of savanna vegetation, even though the occurrence of a definite dry season is significant. Therefore, various types of savanna are found in tropical wet and dry (Aw) climate experiencing mean monthly temperatures ranging from 18°C (64°F) to above 23°C (74°F), and annual rainfalls varying from more than 1700 mm. (67 inches) to as little as 662 mm. (30 inches).

Dry types of wooded savanna, found particularly in Africa and Australia, are associated with low latitude semi-arid (BSh) climates where annual rainfall may be as low as 410 mm. (16 inches). Certain characteristics representative of all climates are common to savannas. These are the occurrence of a definite dry season in which the number of months that are ecologically dry may be as few as three or more than seven. Saturation deficit during

the dry season is moderate to high. Most savanna areas experience a large variability in rainfall from year to year; occurrence of drought is fairly common.

Equally as important as the climatic dry season, are soil-moisture relationships. Soil textural classes may vary from coarse sands with layers of gravel to heavy, compact clays. Thus within an area, certain combinations of soils, topography and drainage combine to produce a moist biological environment able to support broadleaf evergreen forest, while an adjacent area may support only xerophyllous shrub. Soils that are too freely drained will be physically dry, whereas soils that are too poorly drained will be physiologically dry. Thus, in savannas where climate, topography and parent material are the same, a change in vegetation indicates a change in soil or soil-water relationships.

Savanna is a woody-plant/grass complex where the areal density of woody species, generally trees, varies considerably in a well-developed grass cover. It is possible that the climate is sometimes sufficiently dry to maintain the more or less open nature of the savanna, but it seems more likely, that the frequency of fire acts as a greater deterrent to the encroachment of woody species than does climate. Perhaps it is more correct to say, that climate in combination with geologic strata, topography, soils and edaphic conditions provide a delicately balanced forest environment in most tropical areas. The occurrence and intensity of fire appears to have been sufficient to have degraded the forest and woodland cover in most areas, and to have eradicated nearly all woody species in open grasslands. Most savanna vegetation, therefore, is in a state of ecological disequilibrium with the environment. The diversity of vegetation types comprising savannas is such that occasionally all stages from essentially woodland to grass savanna, or even grass steppe, can be found in a few hectares. Selected examples of savanna types illustrate this diversity.

Wooded savanna in Africa covers extensive areas both north and south of the Congo Basin (see maps, Chapter V). In humid sites trees may be more than 20 meters high (66 feet), semi-deciduous, and form a leaf canopy that is thin enough for sufficient light to reach the ground to support a grass cover. Tree species are fire-tolerant, but are unable to withstand fierce fires. Climax vegetation is believed to be a closed woodland with little grass. When fire is excluded, a dense understory of brush quickly becomes established. However, most of this type of wooded savanna is thinned by annual fires which kill new saplings and promote grass understory. In areas where climate or site is dry, trees are mainly deciduous and vary in height from 4 m. to 10 m. (13 feet to 33 feet) high with density of stand depending on edaphic conditions and the nature and extent of human interference. Seldom is woodland continuous for more than a few kilometers, and open grassland surrounds the wooded area (PLATE 11).

In the Brazilian Highlands, the woodland transitional between forest and campo cerrado is termed cerradão. The cerradão of the Planalto Central is physiognomically like a luxuriant campo cerrado, Waibel (1948). The average height of trees is 10 to 15 m. (33 to 50 feet), and at the height of the dry season 20 to 30 per cent of the ground per unit area is estimated to receive the direct rays of the sun. In the adjacent much taller semi-deciduous forest, Waibel stated that only 3 to 5 per cent of the ground is directly exposed to the sun and grasses are not present. In the campo cerrado on the other hand, trees average 4 to 8 m. high (13 to 26 feet), and 80 to 90 per cent of the ground is estimated to receive direct sunlight. Primarily on the basis of soil characteristics, Waibel classifies cerradão as a transitional type of forest, but the campo cerrado is an open wooded landscape composed of clumps of bush and trees densely scattered and interspersed by grass (PLATE 12). The term savanna does not fit well the distinctive vegetation of Central Brazil.



PLATE 11: Regenerating woody species in subhumid, wooded savanna protected from grazing and fire. South Africa (Photo by J. F. V. Phillips).



PLATE 12: Campo cerrado vegetation in the Planalto Central of Brazil (Photo courtesy of T. L. Hills).

The pine woods with a grass ground cover located in Coastal British Honduras, Honduras and Nicaragua are also termed savannas. Located on sandy soils, these savannas have widely spaced trees (Pinus caribaea) with a tall grass ground cover giving an overall appearance of a park-land which is definitely subclimax to a tall mesophytic forest. Pine savannas are definitely fire-maintained. The presence of a dense brush understory composed of hardwood saplings, (oak), thicket and vine is an indication that fire has not occurred for three or more years. Control burning reduces fuel accumulations which would feed fires too intense to be withstood by young pine trees. Methods employed in burning are patterned after the experience, supported by many studies, of foresters and others in the pine forests of southeastern United States

Open savannas are largely perennial mesophytic grasslands in which the various grass species form tussocks isolated from each other. The culms when fully grown form a more or less continuous layer dominating any lower stratum of plants. The density of ground cover depends largely on edaphic conditions. In wet sites, sedges and reeds are dominant forms. Even though grasses may be the dominant vegetation, it is the type and distribution of trees which impart the distinctive characteristics to the various types of open savanna (see Appendix II). Since annual fires are common to grass savannas, all tree forms are phyrophilic and may appear widely scattered, in island-like patches, and as galeria filaments following stream courses. Palms, also fire-resistant, may dominate open savanna areas and occur in upland sites and along wet bottomlands (PLATE 13).

Many savanna trees are adapted to the occurrence of fire by having deep tap root systems, thick bark, the ability to quickly send out buds and new leaves, and to send up suckers or new shoots. In certain species roots are massive rather than branching (PLATE 14). Most of these

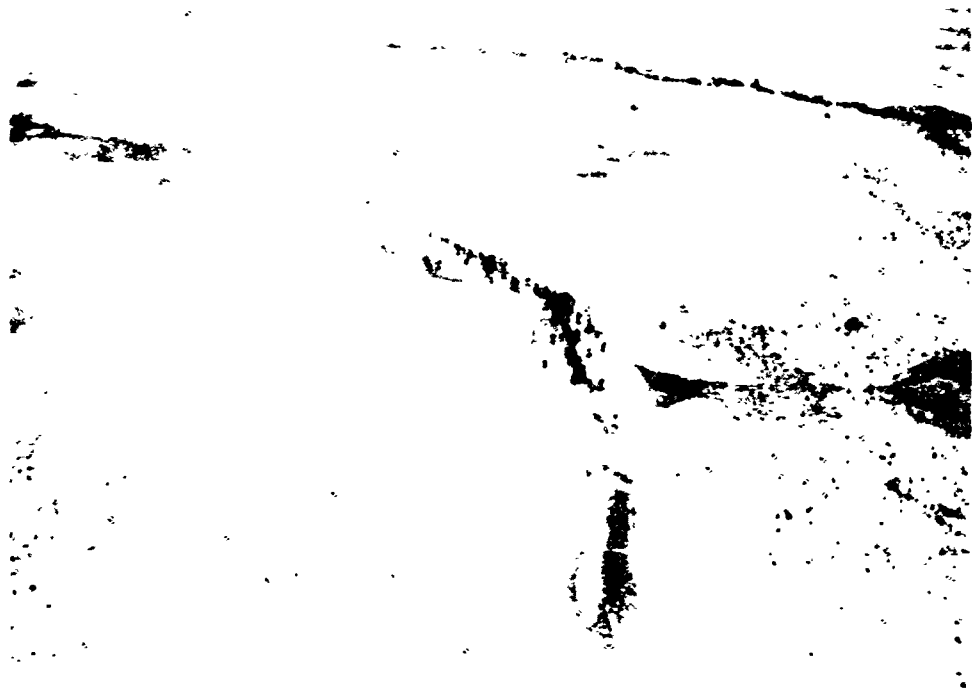


PLATE 13: Scattered bush savanna with galeria forest and palm marsh. Irregular dark patterns on the rolling terrain are recently burnt areas. Color believed due to reddish latosols. Rio Branco Savanna, Brazil (Photo by T. L. Hills).



PLATE 14: Massive root systems of Courbonia edulis (left) and another shrub. These are typical fire-resistant plants of the wooded savanna, Africa, and troublesome regeneration species in open grasslands (Photo by H. J. Van Rensburg).

pyrophiles belong to the legume family in Africa, notably Acacia spp , Brachystegia spp., Isoberlinia spp., and Julbernardia spp. In America, the most conspicuous savanna trees are Curatella americana, Byrsonima spp., Bowdichia virgilioides and Xylopia spp. (see PLATES 17 & 18 p. 111). In northern Australia, eucalyptus is found where fire is not too intense and in drier areas Acacia spp. are common. It is doubtful that natural savannas occur in South and Southeast Asia. Successional stages in clearings in the various types of forest may include grasses and/or bamboo or vine and low tree growth.

Savanna grasses include perennial and annual species which have been subjected to varying degrees of disturbance, such as grazing pressure by domestic animals, concentration of game and frequent fire. As a result of the interaction of all or some of these disturbing factors, much of the grass cover reflects many different stages of degradation and recovery which may persist for varying periods of time as secondary grasslands. Predominant grasses are coarse perennial species that vary in height from 40 cm. to more than 3 m. (16 inches to 10 feet) depending on climate and soil-water conditions. These grasses generally have flat basal and cauline leaves, and propagate from creeping roots or rhizomes. Bermuda grass (Cynodon dactylon) is widespread especially in the pine savannas of Central America. The genus Hyparrhenia characterizes the grass cover of a large part of all tropical savannas between latitudes 20°S and 8°N, and where rainfall is about 762 to 1525 mm. (30 to 60 inches) annually. In Africa, Hyparrhenia spp. are associated with the wooded savannas of Angola, parts of southern Rhodesia and with the broad wooded savanna belt extending from Sudan to Sénégal. When this type of cover occurs as an understory to an undisturbed woodland of Brachystegia or Isoberlinia, it is usually sparse and spindly. When the trees are more open, however, or where clearing and

fire has taken place, the grasses thicken, and Hyparrhenia then becomes a significant member of the grass association, often reaching a height of 2 to 3 m. (6 to 10 feet) and forming dense thickets (Rattray, 1960).

Guinea grass (Panicum maximum) is widely distributed throughout savannas in Africa and America. It reaches its maximum development under warm, moist conditions on fertile soils, and is therefore, often associated with elephant grass (Pennisetum purpureum). Elephant grass is found in the degraded forests and wooded savanna in Nigeria, Ghana, Ivory Coast, Liberia and Sierra Leone. Imperata cylindrica, (sword grass) also is widespread in savannas, particularly in those north of the equator. Fires in both Pennisetum and Imperata are fierce; the latter grass carries fire even when green. The genus Andropogon has a very wide distribution in Africa, but reaches its maximum development north of the tropical evergreen forest; Andropogon spp. and Hyparrhenia spp. are frequently co-dominants in the various types of savanna characterized by a marked dry season, but with annual rainfall greater than 762 mm. (30 inches).

In northeastern Australia, wooded savanna grasses include Heteropogon contortus (black spear grass), Themeda spp. (kangaroo grass) and in parts of the Northern Territory, the annual, Sorghum intrans is widespread among the perennial grasses, Themeda australis, and Sorghum plumosum. Numerous grasses reclaim abandoned clearings in South and Southeast Asia, where on wetter sites elephant grass and bamboo often is combined in a dense thicket. Imperata cylindrica with various Sorghum spp. comprise a typical successional stage.

An important factor affecting the occurrence of fire in the coarse perennial savanna grasses is that they are nutritive and palatable only during early stages of growth. As the grasses mature during the rainy season, they become harsh and woody, and their protein value in proportion

to their bulk is so low that the grasses provide a starvation diet for grazing animals. In most savannas, it is the presence of certain perennial and particularly annual grasses that determine the quality of pastures. Unlike the perennial grasses where translocation of nutrients to the stems and rhizomes occurs at onset of the dry season leaving largely cellulose, certain perennial and annual grasses retain their nutrients in their aerial portions even when dry.

Pastures containing a relative large proportion of the latter grasses are termed sweetveld in southern Africa, whereas pastures dominated by the coarse grasses are termed sourveld. Sweetveld is associated with relative dry climates receiving 510 to 890 mm. (24 to 35 inches) of rainfall annually, whereas sourveld is found in wetter tropical and subtropical climates. Burning is an annual occurrence in the sourveld.

b. Impact of Fire.--The effect of fire on savanna depends on the ratio and spatial distribution of grass to tree in the savanna complex. It also depends on cultural activities (see Chapter IV). However, the response of the two physiognomic units, tree and grass, to fire, or to the absence of fire depends on a multiplicity of strictly regional factors.

In grassveld areas of Africa, fire is widely employed as a tool in pasture management. Sweetveld pastures are burned every three or four years, if at all, because the grasses are palatable to stock during the dry season. The coarser grasses of the sourveld are burned annually to remove dry vegetation and to prevent brush encroachment. It should be noted that for most grassvelds, absence of fire or grazing or both leads to the accumulation of old undecomposed grasses and subsequent deterioration of the sward by encroaching woody plants (PLATES 15 A and B and 16 A and B). Within a few years, the grass cover may die



PLATE 15A: Grassland subjected to annual August (spring) burning, but no mowing or grazing for 7 years. Highland Sourveld, Natal, South Africa (Photo by J. D. Scott).



PLATE 15B: Close-up of the grass sward. Highland sourveld, Natal, South Africa (Photo by J. D. Scott). Compare plates 15A and B with 16A and B.



PLATE 16A: Grassland protected for 7 years against mowing and burning. Note deterioration of grass sward. Highland Sourveld, Natal, South Africa (Photo by J. D. Scott).



PLATE 16B: Close-up of the deteriorated grass sward. Highland Sourveld, Natal, South Africa (Photo by J. D. Scott).

out to such an extent that the percentage of ground cover may be reduced as much as 60 to 70 per cent, resulting in the formation of large bare patches which are colonized by scrub and brush growth (Staples, 1945). The recommended time for burning the grasslands is late in the dry season, or preferably, shortly after first rains. Burning earlier in the dry season may destroy annual grasses before they seed, and weaken perennial grasses by removing their aerial portions before nutrients return to the roots. On the other hand, if burning takes place at onset of first rains, it means that highly inflammable dry grasses are exposed to accidental fire during dry months, and can feed disastrous fires. In addition, severe fire materially affects Themeda triandra, one of the most important grasses for stock in the sourveld and a dominant grass in East African savannas. Experiments conducted by Edwards (1942) on grass plots in Tanzania over a period of 5 to 10 years, indicated that light burning in fire protected plots maintained this valuable grass, but hot fires killed T. triandra and the composition of the grass cover became almost a pure stand of Digitaria abyssinica, a much less valuable species. It should be noted that although the recommended time for burning is shortly after first rains, widespread occurrence of fires during the dry season takes place in non-commercial pastures and woodlands and are attributable to traditional practices among African native peoples.

In Africa north of the Congo Basin, the ecological effects of fire on savanna grasslands are such as to suggest that annual burning should be discouraged. For example, a sample area protected from fire in Sudan had perennial grass cover of Andropogon amplexicaulis, A. gayanus, Hyparrhenia spp. and Cymbopogon giganteus, (Letourneaux and Lechner as cited by Guilloteau, 1957). Each year the fire-protected, coarse, tufted grasses grew denser, and reached their maximum development in three years. Thereafter they became

weakened since they were no longer prevented from fructifying. At the point of exhaustion of the perennial grasses, a shorter annual grass appeared, Pennisetum setosum, which became dominant by the sixth year of the experiment. This grass is excellent fodder, remains green well into the dry season, and is a poor combustible. It appears that for the Sudan area, protection of savanna perennial grasses from fire results in establishment of more nutritious grass insofar as the tree cover permits. Whether continued protection from fire would have resulted in establishment of brush, was not determined. However, the authors concluded that annual fires are detrimental to the natural improvement of tropical pastures in the area.

Nearly a century of burning in Queensland and Northern Territory of Australia by commercial graziers appears to have established a fire climax little changed. The wooded savannas are dominated by various species of Eucalyptus and Acacia. In Queensland, spear grass (Heteropogon contortus) is dominant because it is more fire resistant than the kangaroo grass (Themeda spp.) and blue grass (Dichanthium spp.). Stock selectively feed more heavily on the latter two grasses. In the Northern Territory Sorghum plumosum, Themeda spp. and in wetter climatic areas, the annual grass Sorghum intrans are dominants. All these grasses are fairly nutritive early in the rainy season, but like the sourveld of Africa, quickly lose their protein and are unable to provide more than a starvation diet for cattle. Consequently, widespread burning is practiced primarily to destroy the rank grass and to extend the grazing season as long as possible in order to reduce the period when stock lose weight (Davis, 1959). Burning is directly adjusted to establishing new growth as quickly as possible at onset of rains, or to extend grazing as long as possible into the dry season. Hence, two periods of burning are possible.

In tropical America, burning of open savanna grasslands occurs during or at the end of the dry season. As in the case of Australia, burning is directly related to providing a flush of new grass for stock, reducing brush encroachment and to killing pests. The effect of late season burning on savannas has been lamented in much of the literature, but there are few ecological studies on which to base a sound judgement of the effects of fire on these tropical grasslands.

'Fire's' effects on tropical woody species is no less involved than its effects on savanna grasses. In West Africa, burning early in the dry season is prescribed from Sudan to Sénégal as a measure to reduce accumulation of fuels that would feed intense fires occurring later in the dry season. Early burning is a preventative measure, supported by foresters and conservators to maintain tree growth and to encourage forest regeneration. However, if burning is too early so that fuels are not effectively burned, the regrowth provides a severe fire hazard to the forest and woodland by the end of the dry season. In the grass velds of southern Africa, late burning is recommended as a measure to eradicate woody growth that infests pastures. The same late burns, as has been noted, may also do considerable harm to the quality of the pastures.

Many savanna trees and bushes are adapted to attack by fire. Most species have a great power of recovery in which new buds will begin development and new leaves will unfold at almost any time of the year after damage by fire. This new flush of growth is supported by food reserves stored either in the tree or its root system. Fires early in the dry season attack seedlings and saplings which have yet to establish a tap root system or other adaptations to drought and fire, so that cut-back by fire kills them. On the other hand, such fires cause little damage to mature woody species and therefore would not effect ecological

change in the floristic and physiognomic character of the woodlands, bush islands and palm marshes. Frequent late season fires often lead to mortality of less tolerant canopy trees and reduce size and density of the trees so that gradual thinning may take place. Unless ecological conditions permit, degradation of even fire-resistant savanna species may continue until only isolated trees or small clumps remain (see PLATES 17 and 18).

Indiscriminate and widespread burning can initiate change in vegetation cover which is non-reversible. Few authors consider the campo cerrado of Brazil to have been derived from an extensive forest, but there is ample evidence that many areas now in low brush and grass were once forested. Hardy (n.d.) in studying the campo cerrado of south-east Brazil, concluded that burning contributed greatly to the rapid degeneration of soils after the forest had been felled. This was especially evident in areas where repeated burning took place. Not only was organic residue in the soil lost, but rapid mineralization and loss of nutrients by leaching was accompanied by soil erosion. Accordingly, the edaphic environment was completely altered and forest is prevented from regenerating. Hardy noted that soils supporting campo cerrado are extremely low in nutrients and have all the characteristics of senile soils in transition between kaolinite and the gibbsite-hematite stages of weathering. He concludes, therefore, that campo cerrado is a "deflected" climax, that is, the campo cerrado is an edaphic savanna, supporting low brush and grass as an edaphic climax produced by forest clearing and fire. Very low soil fertility and sub-soil drainage conditions have been offered as explanations for the occurrence of other savannas (Parsons, 1955; Schnell, 1945; Denevan, 1963).

Based on known ecological effects of fire on the various plant communities found in tropical savannas, it is evident that constructive use of fire must include the



PLATE 17: Bush island remnant thinned by frequent fires in the surrounding Trachypogon plumosus grassland. Note burned area in foreground. Northern Rupununi, Guyana (Photo by T. L. Hills).



PLATE 18: Flush of new growth (Trachypogon plumosus) following burn (to the right), and two years unburned growth (to the left) in which a jeep track acted as a fire break. Scattered brush is Curatella americana. Northern Rupununi, Guyana (Photo by T. L. Hills).

proper time of burning. In many cases, fire will favor either grass or trees, but not both. All authorities agree that indiscriminate burning, which is very widespread, is harmful to the total environment, cultural as well as natural.

Studies of the ecological effects of fire have been predicated upon commercial exploitation of either woodland, planted forests or grasslands for cattle and sheep. One should not construe that the widespread occurrence of fire in tropical savannas is determined by policies derived from conclusions obtained from these studies. The land area exploited in intensive commercial enterprises is very small in relation to the area subject to indiscriminate burning, and over vast areas, indiscriminant burning takes place.

c. Potential Combustibility.--High potential combustibility characterizes the various types of savannas. Although fire is possible nearly any season, the presence of a well-defined climatic dry season establishes the combustible period which may extend from three to more than seven months. On the other hand, annual rainfall is sufficiently large in amount to produce fuel quantities exceeding 25 tons/acre. At the onset of the dry season, desiccation proceeds rapidly with sedges and grasses becoming harsh and dry within periods as short as three days depending on weather conditions. As the dry season advances, woody growths become tinder dry and are able to sustain fierce fires. The actual behavior of fire in tropical savannas depends on the proportion of woody species to grasses and their respective areal distribution. In open savannas, bush islands may be sufficiently large enough to escape the attack of fires sweeping over the grasslands. Likewise, galeria forests may act as barriers to unlimited sweep of grass fires. In wooded savanna areas, the heterogeneous mixture of types of fuel arranged at various levels may support very intense

fires lasting for a considerable period of time. Since the various fuel sizes do not burn at equal rates, multiple fire fronts may occur. Grassland fires, on the other hand, are surface types, which although intense, have a narrow burning zone.

Paradoxically, semiarid tropical areas experience severe drought of long duration which is most favorable to high potential combustibility, but low annual rainfall and high rainfall variability severely limits the quantity of fuel present. Protracted periods of rapid and severe desiccation of vegetation produces a condition of high inflammability. Furthermore, semiarid brush frequently comprises aromatic species that are high in inflammable oils and resins. On the other hand, ignition of the vegetation from natural causes is rarely mentioned in the literature. A frequent explanation given is that lightning is associated with shower activity heralding the onset of rains. At that time, much of the land, particularly in Africa, has already been burnt preparatory to clearing for cropping and grazing. During the protracted dry season, prevailing climatic conditions tend to be unfavorable for convective overturning of the lower atmosphere necessary to cloud buildup. Although fires burn fiercely in semiarid scrub and grass, and fuel spacing permits rapid fire spread, total fuel quantity per unit area is low, particularly in predominantly steppe regions subject to intensive nomadic and commercial grazing.

d. Long Term Effects of Fire.--No accurate assessment of the areal extent of fire-induced degradation of major vegetations formations is possible (Richards 1964). Aubréville. (1947) doubted that much virgin tropical rain-forest remains in West Africa. Richards believes that for Asia, undisturbed forests are probably limited to non-continuous areas of varying size located in rugged highlands and other inaccessible parts of Southeast Asia, Oceania and Northern Australia. Puri (1960), states that savanna grass-

lands are not natural to India, but represent degraded forest areas repeatedly burned. Numerous authors suggest that large portions of Latin America, once believed to possess virgin tropical rainforest and other types of humid forest, actually are not climax but mature stages of second growth (Budowski, 1956; Bartlett, 1956; Popenoe, (1963): Denevan, 1965; Dansereau, 1948; Gordon, 1957, and many others). Much if not most of the Caribbean Islands have little or no virgin vegetation. Fires and their effects on the vegetation in parts of Mexico and Central America have been reported by numerous writers (Budowski, 1958; Fuson, 1963; Johannessen, 1963).

The role fire plays in savannas of the tropical world is a dominant one. For most savanna areas annual burning occurs, and there is little doubt that frequent fire both transforms certain landscapes and maintains grassland in others. The role of fire in modifying and maintaining existing savannas is represented by a vast literature. On the other hand, the origin and spread or retreat of savanna vegetation are open questions. Hills (1965), in reviewing the problems of savanna research, assumes that in most places fire maintains or even may extend savanna vegetation. He also notes instances of forest encroachment on former savanna. He concludes, however, that among the many explanations offered for the origin of savanna, no one factor, be it climatic, edaphic, geomorphic, biotic or anthropic, has universal acceptance as a single convincing view point.

D. Fire and Selected Phenomena

1. Fire and Soils.--The effects of fire on soil are both direct and indirect, temporal and permanent. The most obvious direct effect of a burn is the exposure of the soil to the weather, the reduction of vegetation and soil humus to ash and the immediate availability of nutrients to crops. In many tropical areas, it is difficult to determine a permanent change occurring in forest soils, particularly if

the forest fallow cycle is long enough to permit regeneration of fairly mature tree growth. Elsewhere in the tropics, the removal of forest cover is believed to initiate permanent change as, for example, in parts of the campo cerrado of Brazil. Finally, numerous authors have referred to the sharp differences between savanna and forest soils. In many areas, savannas and forests occupy distinctive types of landforms, each differing in their geology, topography, and geomorphic evolution. The role of fire in the latter case may be tenuous, but in degraded forests, soil changes have been observed leading to characteristics similar to those observed for savanna soils. Somewhat arbitrarily then, the effects of fire are divided into those that are direct and temporal and those that appear to be indirect and more lasting.

a. Direct Effects.--Considerable research has been conducted on changes that occur when forest soils are subjected to burning. Of particular importance is whether significant change occurs in the chemical and physical properties of soils. Although piled slash feeds intense fire that may burn more than 24 hours, the penetration of heat is measurable to about 80 cm. depth. The downward movement of heat, however, may be significant to only about 20 cm. depth. In grasslands, the penetration of heat rarely exceeds 5 to 10 cm. There is sterilization of the upper soil leading first to a reduction or total destruction of microorganisms, and then reestablishment of microbial activity, often within a week following the burn. Shortly thereafter, microbial activity may rise above the level preceding fire due to increased rates of mineralization in the exposed soil, the presence of ash nutrients, and in some cases a rise in pH. Particularly in savanna grasslands, fire stimulates microbial activity because grasses, which suppress nitrification, are burnt, and microorganisms respond to the greater availability of nitrogen (Nye and Greenland, 1960).

Considerable attention has been focused on the effect of fire on organic material, availability of nutrients, pH and related factors in soils. There is no question that burning felled forest or grassland produces varying amounts of phosphorus, potassium, calcium and magnesium, while nitrogen and sulphur evolve as gases to the atmosphere. Nye (1959) lists estimated amounts of nutrients available in the aerial parts of a West African forest 40 years old and contrasts this with an area of tall grass (Andropogoneae) containing 48,000 pounds of woody plants per acre (Table 11). Shrub and tree growth in the Guinea savanna of Ghana is very slow, probably due to nitrogen deficiency induced by fixation by the grasses of the low amount of available nitrogen.

TABLE 11

ESTIMATED QUANTITIES OF NUTRIENTS IN AERIAL PORTIONS OF
TROPICAL FOREST AND WOODED SAVANNA, GHANA, AFRICA

Nutrients released upon burning (pounds/acre)	P	K	Ca	Mg
Tropical forest 40 years old	112	731	2,254	309
Wooded savanna: Herb layer	7	41	31	23
Wood portion 48,000 lbs/acre	13	130	210	56

After Nye, 1959

Nutrients contained in the ash are water soluble and are absorbed by the clay fraction of the soil. Rapid loss of these nutrients occurs as leaching proceeds. However, abandonment of cultivated fields is as much due to weed and brush infestation and the amount of labor required

to maintain the field, as it is to loss of soil fertility. Although nitrogen is normally lost to the atmosphere, tests following burning often show no loss or even an increase in available nitrogen. The explanation frequently offered is that for soils where the decomposed organic layer is not entirely consumed, the action of heat on the organic matter releases nitrogen to the soil.

Equally variable have been reports on the effect of fire on pH of the soil. Numerous studies indicate that a sharp increase in pH occurs as alkaline ash is incorporated in the soil. However the effect is temporary: about one half to two thirds of the increase is lost in the first year of crop production and by leaching due to heavy rains. Decline in pH is gradual thereafter returning to original values in 2.5 to 4 years. In wooded savannas and open grasslands, both an increase in pH and no change in pH following fire have been reported, but studies are inconclusive since so many variables determine soil response to fire.

Likewise there are mixed reports concerning the immediate effect of fire on the physical properties of soils. In parts of Africa, India and South America, it has been noted that incorporation of large amounts of ash tended to deflocculate the colloidal gels in clayey soils, but had little effect on sandy soils (Griffith, 1946; Renard, 1949; Freise, 1934). Heavy soils are frequently found in savannas occupying level to undulating sites. Although the presence of loam and clayey soils is due to geomorphic evolution of the landscape, the inferior porosity of the soils may be due in part to deflocculating of surface particles caused by ash from annual fires. Superficial induration of savanna soils has been noted by a number of researchers and has been attributed to the impact of heavy rains on bare ground, and capillary action in the dry season (Aubréville, 1947; Waibel, 1948; Eden, 1964).

Clearly, the number of factors which govern the immediate response of soil to fire depends not only on the pedogenetic characteristics of the soil, but on vegetation, site, edaphic conditions and other factors. Even though there have been cases where fire has been the direct cause of breakdown of soil structure and increase in bulk density of tropical soils, there is an equal number of studies where no deterioration occurs. Baldanzi (1959) concluded that the amount of heat transmitted to the soil from burning grass plots in Curitiba, Brazil was decidedly insufficient to damage the soil. The heat fosters dehydration and the coagulation of colloids and promotes aggregates in the soil. Studies conducted in Colombian coffee soils however indicated that the percentage of large soil aggregates in the upper horizon was materially increased by burning with resulting improvement in soil permeability (Suarez de Castro, 1953). Joachim and Kandiah (1948) carried out experiments over several years to find out whether or not shifting cultivation as practiced in Ceylon degraded the soils. The authors stated that chena (shifting) agriculture had no adverse effect on soil structure that would not occur as a result of the usual methods of preparation of a forest soil for any other type of rotational agriculture. Nye (1959), in discussing rainfall acceptance and percolation tests on some East African soils of fairly high clay content, concludes that the improvement in structure and other physical properties by protecting grass fallows from fire was obliterated in the first year of subsequent cultivation. The physical properties of most latosols are inherited from the soil itself, particularly its mineral composition as established by pedogenetic processes. Consequently, the combination of iron oxide and kaolinite is very important to stable microaggregation. Most heavy red tropical soils possess remarkably stable physical properties. While light sandy soils tend to indurate easily and erode severely.

Analyses of soils from 30 fields in various stages in the shifting cultivation cycle in the Polochic River Valley, northern Guatemala, indicated a high porosity and low values for bulk density of all soils sampled (Popenoe, 1959). Consequently, the heavy rains were readily absorbed by the soils, and little surface erosion was observed on cultivated slopes. Popenoe noted that most of the erosion was by landslides.

b. Indirect Effects.--The action of fire in altering the microclimate and biological environment in tropical areas can initiate significant changes in soils. Particularly, the degradation of forest and establishment of savanna is believed to be accompanied by degradation of the forest soil. Such changes occur over considerable periods of time, hence knowledge of processes operative in degrading forest soils is derived largely from comparative studies of soils under different, but adjacent types of vegetation. More numerous are the studies investigating the effects of cultivation on forest soils, and the relationship between effects noted and cultural practices. Few studies have investigated the gradual changes occurring in soils once forested. However, a considerable literature has developed supporting the view that in addition to a lessening of fertility, degraded soils become more compact and develop impeded drainage. In turn, the effects of poor soil drainage and fluctuating ground water table contribute to the formation of indurated hardpan, widely observed in savanna areas.

Although the physical-chemical properties of tropical forest soils do not compare with temperate forest soils, they are superior to those associated with savannas. Generally, forest soils are favored over tropical grassland soils because they are easily cultivated due to their open structure and because they have a fair amount of organic material that can be reduced by fire to contribute to ash fertilizer. A tall forest may contribute 4 tons of dry litter and 2 tons of new roots per acre per year. The total supply of nutrients

derived from organic matter is small because of an intense nutritive cycle that quickly returns bases to new vegetative growth. However, the same cycle maintains nutrients in the surface layer, particularly phosphorus.

Savanna soils commonly have less favorable characteristics. Frequently they are either derived from coarse colluvial materials and therefore are droughty, or they are heavy, fine-textured and possess inferior drainage characteristics. Savanna soils are low in surface organic matter. A regularly burned grassland contributes nutrients and organic matter primarily in the root zone, and may add less than 2 tons per acre per year. Grasses suppress exchangeable nutrients so that fertility is low. Degradation of savanna soils proceeds more rapidly than is the case for forest soils. Depending on cultural practices, the impact of shifting cultivation is negligible on forest soils if a fairly long forest fallow period ensues. On the other hand, cultivation of savanna soils, notably in Africa and Asia, requires removal of the sod and hoeing each year prior to planting. Compaction of soils with attendant loss of pore volume is likely to be more severe in grassland soils.

2. Fire and Biota

a. Vegetation and Macrofauna.--Certain aspects of the complex and subtle interrelationships between fauna and habitats are of significance to the study of fire. The use of fire in hunting, driving game, forest gathering and other activities is culturally controlled. Of importance to the physical habitat is the effect of large animals on vegetation considered as potential fuel. The trampling and browsing of elephants, for example, can reduce vegetation as effectively as fire.

The movement of macrofauna along well-defined routes quickly establishes trails that may act as fire breaks. Even for open grasslands, a criss-cross pattern often develops due to migration of wild animals and movement of domestic stock. In wooded savannas, where trees appear

in isolated clumps, it has been reported that stock, particularly cattle, pulverize the ground cover as they seek shade during the midday. Consequently, fire cannot be sustained around the wooded areas with the effect that woodland patches are preserved as bush islands. Photos depicting the effects of drought in South African game preserves showed that trampling, grazing and browsing by game attracted to the few remaining water holes completely devastated the natural vegetation in roughly circular areas 3 km. in radius. Although this represents extreme conditions, it is clear that most areas close to water holes will support a sharply reduced vegetative cover.

The macrofauna of American savannas are noted for their poverty compared to the richness of the highly specialized fauna of the adjacent tall forests. Whereas the forest habitat has been stable for a long period of time, the savanna grasslands are probably not very old (Budowski, 1956). Deer, rabbits, quail and other species only slightly differentiated from North American types are the most numerous.

b. Vegetation and Termitaria.--The role of termites in molding savanna landscapes is well-documented. Of interest to the subject of fire is that abandoned termite mounds frequently provide microtopographic relief propitious to the establishment or maintenance of forest communities. The distribution of termite mounds definitely favors wooded savanna environments. Termite mounds are constructed by the termite worker filling its mouth with clay drawn from the subsoil, then it picks up a sand grain which it carries to a selected site and places into position. The saliva-wetted clay is squirted around the grain which is pressed into place (Hesse, 1955). Termite mounds have been excavated showing that in their need for clay, workers have dug down 4 m. to as much as 12 m. (13 to 40 ft.) and lateral galleries may run to a radius of 200-300 m. (660 to 990 ft.). Kellogg and Davol (1949) noted that in certain savannas

in the Belgian Congo, termite mounds covered 15-30 per cent of the total area. Mounds often stand 4 m. (13 ft.) above ground level and are about 7 m. (23 ft.) broad. Termite mounds in the Sudan have been described as being 5 m. (16 ft.) high and 19 m. (63 ft.) across.

Termite mounds are remarkably persistent features of the landscape, even in climates receiving as much as 1200 mm. (47 in.) in a well-defined rainy season, and may vary in height from 3 m. to 10 m. More importantly, occupied mounds are bare of vegetation and hence are not affected by fire. Since about two-thirds or more of the number of mounds in a given area are abandoned, the vegetation that becomes established on the mound commonly is composed of woody species. Boughey (1963) states that large undisturbed mounds in Central Africa are clothed with vegetation resembling a dry deciduous forest. There is a dominant tree layer, below which is found a more or less dense thicket of small trees, shrubs and woody climbers. Many species are relatively fire-sensitive, indicating that annual fires of the savanna grasslands do not penetrate the center of mound vegetation. It is not clear but it is believed that the vegetation of these large mounds represent survival of what was a late Tertiary plant community (Boughey, 1963).

In many savannas abandoned mounds are micro-sites capturing woody species. In the Rupununi savannas, Guyana, even small mounds frequently have at their base a few pyrophilic species, commonly Curatella americana (PLATE 19). Whether bush islands or patches of woodland can start from the establishment of a few trees around a mound is not known. In the Ivory Coast in wooded savanna with vestiges of dense forest, patches of woodland are established which very often are on a termite mound. These patches are usually scorched, but are not often penetrated by fire. The resistant pyrophiles are found at the outer margins of the wooded patches, while less fire-tolerant species are found in the center (Bergeroo-Campagne, 1956). These in turn protect a larger



PLATE 19: Micro-topographic effect of termite mounds is to provide sites favorable to establishment of woody pyrophilic species in open savanna. Northern Rupununi, Guyana (Photo by T. L. Hills).



PLATE 20: Patterns of two wind-driven fires in progress (A) occurring on the flood plain of the Rupununi River. Dense evergreen and swamp forest communities (B) border a meandering tributary. Finely-textured white sands (C) rise 50 feet above the flats. Northern Rupununi, Guyana (Lat. $3^{\circ}50'N$, $59^{\circ}20'W$). (Photo by Hunting Aero-surveys, Ltd., courtesy of T. L. Hills).

zone from the invasion of grasses, allowing the establishment of new fire-resistant woody species on the periphery. In this way, the author believes forest communities can become established, and those possessing concentric differentiation in fire tolerance are old communities.

E. Areal Patterns of Burning

The fact that there is an infinite number of possible areal patterns of burning should not act as a deterrent to the search for useful generalizations based on subjectively relating environmental conditions to known characteristics of fire behavior. Surprisingly few observations concerning areal patterns of burning are recorded in the literature, considering the abundant opportunities to view fires in progress. Burning is neither a chaotic nor random phenomenon, but follows known processes controlled by various physical laws (see Chapter II and Appendix I). Among the more important factors influencing the pattern of burning would be the state and characteristics of the natural vegetation, the type of terrain, and wind direction and velocity.

The patterns of burning in tropical forests are determined largely by the cultural practices of shifting cultivators. Factors of selection of site, time of burning in the agricultural year, amount of area cleared each year and the forest fallow cycle are presented in Chapter IV. The time of burning in relation to climate and vegetation is presented cartographically and analyzed in the accompanying text (see Chapter V). Few useful generalizations concerning the pattern of burning can be made based solely on conditions in the physical environment.

The area of forest patches subject to burning rarely exceeds 2 hectares (5 acres), even though among certain peoples a larger area of forest is felled and the brush collected to the site to be planted (chitemene). The encircling forest limits fire spread. Consequently,

the pattern of burning reflects the population pressure on the land, the forest fallow period and the site preferences of shifting agriculturalists. In many cases, clearing the forest takes place where forest and savanna meet. The opportunity for accidental fire in the neighboring grasslands is considerable. The pattern of clearing and especially the plots recently burned can be identified from aerial photographs (see PLATES 20 and 21).

Savanna grasslands have broad expanses of fine-textured fuels possessing large surface exposure to the air within the vegetation zone. Since grasses quickly dry following the beginning of a period of little or no rainfall, fire sweeps rapidly through the fuel matrix commonly in a single flame zone of narrow width. The pattern of burning varies according to a host of local environmental factors, but three important factors, in addition to combustibility of the grasses, are fuel quantity, prevailing wind direction, and mean velocity of the wind.

In open grassland savannas relief is frequently level to undulating, and obstructions to fire spread are limited to gallery forest and isolated wooded areas. Depending on the quantity of fuel present, fires move downwind, driven by tradewinds noted for their constancy of direction and high mean wind velocity. If fire occurs during brisk wind, a linear pattern of burning develops in which the flame advances as spearheads sometimes separating and then reuniting (PLATE 20). The constancy of wind direction also accounts for the linear pattern, and under such conditions fires have recently traveled distances in excess of 200 km. (124 mi.) in parts of Africa north of the Congo Basin. In 1960, a fire in the northern Rupununi savanna, Guyana, traveled uninterruptedly from Annai to south of Pirara for an estimated distance of 80 km. (50 mi.) (Waddell, 1963).

Where fuel quantities are modest and winds exceed 4.5 m/sec. (10 mph), there frequently results a linear striped pattern composed of a sequence of burned and unburned



PLATE 21: Striped burn patterns (A) in open grassland of an alluvial lowland. Galeria forest (B) with an abrupt forest-savanna boundary. Abandoned clearings (C) in various stages of regeneration. Riverine, evergreen forest. Rupununi, Guyana (Lat. $3^{\circ}28'N$, $59^{\circ}35'W$) (Photo by Hunting Aerosurveys, Ltd., Courtesy of T. L. Hills).



PLATE 22: Alternating burned and unburned savanna grasses (striped pattern) produced by wind driving flames through limited grass fuels at such velocity as to limit lateral fire spread. Rupununi, Guyana (Photo by T. L. Hills).

narrow bands of grass. This phenomenon is caused by the prevailing wind driving tongues of fire through a modest quantity of fuel at such a speed and constancy that little or no lateral burning occurs (PLATES 21 and 22). A diagrammatic outline of this process is shown in Fig. 15 (Waddell, 1963).

The occurrence of a striped pattern of burning is widespread. Numerous authors have noted similar patterns in the coastal savannas of Ghana, and in the parallelism of grass swards penetrating woodlands in Central and Southern Africa (Aubréville, 1947; Boughey, 1963; Phillips, 1964).

Often there is a relationship between the position of termite mounds and striped patterns. Thus the shrub savanna lying south of the tropical rainforest in Ghana is regularly and conspicuously patterned (Boughey, 1963). The stripes lie parallel to the prevailing winds, but unburnt portions coincide with the lee side of termite mounds, in which spear-shaped patterns of unburnt grass may extend down wind distances of up to 100 to 200 m. (330 to 660 ft.) or more.

The effect of light winds and low fuel quantities can also be significant. Again in the Rupununi, a jeep track across a scattered bush savanna dominated by Trachypogon plumosus and Curatella americana was a barrier to fire spread under presumably light wind conditions. Fire propagated slowly from one grass tussock to another, halting at the jeep track (PLATE 18, p. 111).

The diurnal variation in winds, which tend to become light and variable at night, is significant to patterns of burning in open savannas. Boughey in a personal communication has witnessed grass fires all the way from the coastal savannas in the Ivory Coast, Nigeria and Ghana, through the various savanna types of the hinterland to the smaller but persistent fires in the short annual grasslands around Lake Chad. Flying over the area at night, he noted that fires

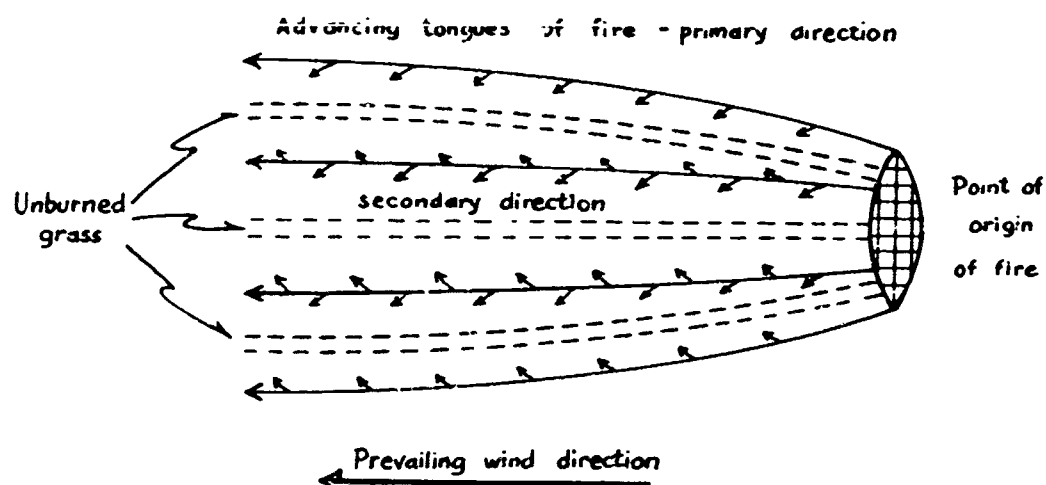


Fig. 15. Diagrammatic Representation of the Burning Process Resulting in a Striped Vegetation.

form fronts that were great arcs stretching for miles.

Finally, the pattern of burning in open grasslands on rolling terrain reflects the factor of terrain roughness. In the Rio Branco Savanna, the windward side and crests of the rolling uplands are burnt, but intervening lee hillsides and vales escaped fire. From the air, the pattern of burn is indicated by the darker tone of the landscape believed due to the reddish latosols becoming visible through the fire-thinned vegetative cover (PLATE 13, p. 101).

REFERENCES CITED

- Adlard, P. G. (1961) The background to a burning policy, Dept. of Forestry and Game, Southern Rhodesia, reprint, 11 pp.
- Aubréville, A. M. (1947) The disappearance of tropical forests of Africa, Unasylva, 1, No. 1:5-11.
- _____, (1949) Climats, forêts et désertification de l'Afrique tropicale, Soc. d'Edit. Géograph., Marit. et Colon., Paris, 352 pp.

- Aubréville, A. M. (1953) Les expériences de reconstitution de la savane boisée en Côte d'Ivoire. Bois et Forêts des Tropiques, 32:4-10.
- Aubréville, A. P., DuVigneaud, A. C., Hoyle, R. W. J., Keay, F. A., Mendonça, and R. E. G. Pichi-Sermolli. (1959) Vegetation map of Africa south of the Tropic of Cancer, Scale 1:10,000,000. Published for L Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale, with assistance of U.N.E.S.C.O., by Oxford Univ. Press. Explanatory notes by R. W. J. Keay.
- Baldanzi, G. (1959) Efeito da queimada sobre a fertilidade do solo. Boletim Técnico do Depto. de Prod. Vegetal. Secretaria de Agr. do Paraná. No. 1. 56 pp.
- Bagnouls, F. and H. Gaussen. (1953) Periode de sècheresse et végétation, C. R. Ac. Sci., 236. No. 10:1075-1077.
- _____, (1957) Les climats biologiques et leur classification, Ann. de Géographie, 66(355):193-220.
- Bartlett, H. H. (1956) Fire, primitive agriculture and grazing in the tropics, In: Thomas, William Jr., (ed). Man's role in changing the face of the earth. University of Chicago Press, Chicago. pp. 692-720.
- Bergeroo-Campagne, M. B. (1956) L'agriculture nomade. Vol. I, Collection F.A.O., Nations Unies pour l'Alimentation et l'Agriculture, 230 pp.
- Bouhey, A. S. (1963) Evolution of termite mounds in central Africa, Proceedings of the Central African Scientific and Medical Congress held at Lusaka, Northern Rhodesia, August 26-30, 1963, pp. 333-341. Pergamon Press, Oxford.
- Budowski, Gerardo (1956) Tropical savannas, a sequence of forest felling and repeated burnings, Turrialba, 6, No. 1-2:23-33, reprint: Mus. de Cien. Nat., B., 6/7(1/4):63-87. (1960)
- _____, (1958) The ecological status of fire in tropical American lowlands, Acta 33º Congreso Interamericano de Americanistas, San Jose. 1:264-278.
- _____, (1962) Forest succession in tropical lowlands, Centro Tropical de Investigacion y Enseñanza para Graduados, Turrialba, Costa Rica, 3 pp. (mimeogr.).
- Chambers, J. (1961) An environmental comparison of Southeast Asia and the island of Hawaii, Research Study Report 38, Headquarters Quartermaster Research and Engineering Command, U.S. Army, Natick, Massachusetts, 30 pp.
- Champion, H. G. (1929) The regeneration of tropical evergreen forests (rainforest), Ind. For., 55:429-446. 480-494.

- Credner, Wilhelm (1935) Siam: das Land der Tai: eine Landeskunde auf Grund eigener Reisen und Forschungen., J. Engelhorns Nachf., Stuttgart, 422 pp.
- Dansereau, Pierre (1948) The distribution and structure of Brazilian forests, Bull. du Service de Biogéographie, No. 3, University of Montreal, Montreal, 17 pp. Reprint from: Forestry Chronicle, 23:261-277. (1947)
- Davis, Charles M. (1959) Fire as a land use tool in north-eastern Australia, Geog. Rev., 49:552-560.
- Denevan, W. M. (1963) Physical geography of the Planalto Central, Pt. II, Survey of the agricultural potential of the Central Plateau of Brazil, Am. Intern. Assoc. for Econ. and Soc. Devel., Rio de Janeiro, Brazil, pp. 18-36.
- _____, (1965) The campo cerrado vegetation of central Brazil, Geog. Rev., 55, No. 1:112-115.
- Dessens, Henri and Jean Dessens (1957) Étude préliminaire des cumulus et des pluies obtenues par convection provoquée, Puy de Dôme, Observatoire, Bull., pp. 47-60.
- Eden, M. J. (1964) The savanna ecosystem - Northern Rupununi, British Guiana, McGill University Savanna Research Project, Savanna Research Series No. 1, McGill University, Dept. of Geography, Montreal, 216 pp.
- Edwards, D. C. (1942) Grass burning, Emp. Jour. of Exp. Agric., 10:219-231.
- Foley, J. C. (1947) A study of meteorological conditions associated with bush and grass fires, Australia Bureau of Meteorology, Bull. No. 38.
- Freise, F. W. (1934) Beobachtungen über den Verbleib von Niederschlägen im Urwald und der Einfluss von Waldbestand auf den Wasserhaushalt der Umgebung, Forstwissenschaftliches Centralblatt, 56:231-245.
- _____, (1936) Das Binnenklima von Urwäldern in subtropischen Brasilien, Petermanns Mitteilungen, 82:281-289.
- Fuson, Robert H. (1963) The origin and nature of American savannas, Geographic Education Series No. 2, National Council for Geographic Education, Norman, Oklahoma, 34 pp.
- Gausson, H. (1954) Théories et classification des climats et microclimats, Congrès Internat. Bot., Sect. 7 et 3: 125-130.
- Gordon, B. LeRoy (1957) Human geography and ecology in the Sinu country of Colombia, Ibero-Americana, 39, University of California Press, Berkeley and Los Angeles, 136 pp.
- Griffith, A. L. (1946) The effects of burning on the soil as a preliminary to artificial regeneration, Ind. For. Bull., 130, 34 pp.

- Guilloteau, J. (1957) The problem of bush fires and burns in land development and soil conservation in Africa south of Sahara, Sols Africains, 4, No. 2:64-102.
- Hardy, F. (n.d.) Edaphic savannas in tropical America, (with particular reference to those caused by nutrient deficiency), Instituto Interamericano de Ciencias Agrícolas, Turrialba, Costa Rica. 26 pp. (mimeogr.)
- Hesse, P. R. (1955) A chemical and physical study of the soils of termite mounds in East Africa, Jour. Ecol., 43:449-461.
- Hills, Theo L. (1965) Savannas: a review of a major research problem in a tropical geography, Canadian Geographer, 9: 216-228.
- Joachim, A. W. R. and S. Kandiah (1948) The effects of shifting (chena) cultivation and subsequent regeneration of vegetation on soil composition and structure. The Tropical Agriculturist, (Ceylon). 104:3-11
- Johannessen, Carl (1963) Savannas of interior Honduras. Ibero-Americana, 46:1-173.
- Keay, R. W. J. (1959) Derived savanna - derived from what? Bull. IFA, Ser. A., Sci. nat., 21:427-438.
- Keetch, J. J. (1959) Unifying fire danger rating - progress toward a national system. Fire Control Notes, 20(3): 87-88.
- Kellogg, C. E. and F. D. Davol (1949) An exploratory study of soil groups in the Belgian Congo. Institut National pour l'Etude Agronomique du Congo Belge, Série Scientifique, No. 46. 73 p.
- Larkins, A. W. (1958) The effect of wind changes on fire, Proc. Fire Weather Confr., Melbourne, Confr. Paper No. 5.
- McArthur, A. G. (1964) Fire Control in Australia. paper presented at the Forest Fire Study Tour June 1964, U. S. Department of Agriculture Forest Service. Wash. D.C.
- Mizon, E. A. (1958) Quantitative forecasting of temperature and dew point, Proc. Fire Weather Confr., Melbourne, Confr. Paper No. 13.
- Nye, P. H. (1959) Some effects of natural vegetation on the soils of W. Africa and their development under cultivation, Tropical Soils and Vegetation: UNESCO Abidjan Symposium, 1959, pp. 59-63.
- Nye, P. H. and D. J. Greenland (1960) The soil under shifting cultivation, Technical Comm. No. 51 of Commonwealth Bur. of Soils, Comm. Agr. Bur. Harpenden, 140 pp.
- Parsons, James (1955) The miskito pine savanna of Nicaragua and Honduras, Annals. A.A.G., 45:36-63.
- Phillips, J. (1964) Personal communication.

- Phillips, J. (1965) Fire - as master and servant: Its influence in the bioclimatic regions of Trans-Saharan Africa, Proc. Fourth Annual Tall Timbers Fire Ecology Conf., Tallahassee, Florida, p. 7-109.
- Poore, M. E. D. (1963) Problems in the classification of tropical rain forest J. of Trop. Geog., 17:12-19.
- Popenoe, Hugh (1959) The Influence of the shifting cultivation cycle on soil properties in Central America, Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association, 1957, 7:72-77.
- _____, (1963) The pre-industrial cultivator in the tropics, Proceedings and papers of the IUCN 9th Technical Meeting, Nairobi, Kenya, Sept. 1963, Part I: Pre-industrial man in the tropical environment, IUCN Publications new series No. 4, 1964, pp. 66-73.
- Puri, G. S. (1960) Indian forest ecology: a comprehensive survey of vegetation and its environment on the Indian Sub-continent, Oxford Book and Stationery Co., New Delhi and Calcutta, Vol. I, pp 1-318, Vol II, pp. 319-710.
- Rainbird, A. F. (1958) The problem of wind in the prevention and control of bush fires, Fire Weather Conference, Melbourne, Australia, July 1958. Proc., No. 6, 12 pp.
- Rattray, J. M. (1960) The grass cover of Africa, FAO, Agricultural Studies No 49. Rome, 168 pp.
- Reifsnyder, W. E. (1960) Forest fire control, McGraw-Hill Encyc. of Sci and Tech . 5:451-455.
- _____, (1962) Weather and fire control practices, Fifth World Forestry Congress, 1960. Proc., No. 2:835-841.
- _____, (1965) Symposium on forest fire research at Tenth Pacific Science Congress--University of Hawaii, August 31, 1961. Fire Research Abstracts and Reviews, No. 2:73-75.
- Renard, M. (1949) Les feux de brousse du Soudan, Bull. Agric. Congo Belge. 40:1919-1932.
- Richards, P. W., A. G. Tansley and A.S. Watt (1940) The recording of structure, life form and flora of tropical forest communities as a basis for their classification, Jour. of Ecol., 28:224-239.
- Richards, P. W. (1952) The tropical rain forest: an ecological study. Cambridge, The University Press, 450 pp.
- _____, (1964) Personal communication.
- Riehl, H. (1954) Tropical Meteorology, McGraw-Hill Book Co., N. Y., 392 p.
- Schneil, R. (1950) La forêt dense: Introduction à l'étude botanique de la région forestière de l'Afrique Occidentale avec clef de détermination pour les principales espèces arborescentes, Paris. Paul Chevalier, 330 p.

- Schroeder, M. J. and C. M. Countryman (1960) Exploratory fire-climate surveys on prescribed burns, Monthly Weather Review, 88(4):123-129
- Specht, R. L. (1958) The climate, geology, soils and plant ecology of the northern portion of Arnhem Land, Amer. Austr. Sci. Exped. to Arnhem Land, Melb. Uni. Press, 3:333-413.
- Stocker, G. C. (n.d.) Notes on the occurrence and effects of vegetation burning in the Northern Territory, (Manuscript, in press), 18 pp.
- Stoddard, H. L. Sr. (1962) Some techniques of controlled burning in the deep Southeast, Tall Timbers Fire Ecology Conference, First Annual, 1962, pp. 133-144.
- Stamp, L. D. (1925) The vegetation of Burma from an ecological standpoint, Thacker, Spink and Co., Calcutta, 65 pp.
- Staples, R. R. (1945) Veld burning, Rhodesia Agric. Jour. 42, No. 1:44-52.
- Suarez de Castro, Fernando (1953) Algunos efectos de las quemadas sobre el suelo y las cosechas, Bol. Informativo, 4, No. 41:9-32, Centro Nacional de Investigaciones de Cafe, Federacion Nal. Cafeteros, Chinchina, Colombia.
- Taljaard, J. J. (1955) Stable stratification in the atmosphere over southern Africa Notos 4(3):218-219.
- Thornthwaite, C. W. and J. R. Mather (1955) The water balance, Publ. in Climatology, Laboratory of Climatology, Vol. 8(1): 104 p.
- Thornthwaite, C. W. (1948) An approach toward a rational classification of climate, Geogr. Rev., 38(1):55-94.
- Tothill, J. D. (ed.) (1948) Agriculture in the Sudan, Oxford University Press, London, 973 pp.
- Vignal, P. (1956) La disparition de la forêt malagache des hauts plateaux, Bois et For. des Trop., 49:3-8.
- Waddell, Eric W. (1963) The anthropic factor in a savanna environment, M. A. thesis, McGill University, Department of Geography, Montreal, 203 pp.
- Waibel, Leo (1948) Vegetation and land use in the Planalto Central of Brazil, Geog. Rev., 38, No. 4:529-554.
- Walter, H. (1955) Die Klimadiagramme als Mittel zur Beurteilung der Klimaverhältnisse für ökologische, vegetationskundliche und landwirtschaftliche Zwecke, Ber. Deutsch. Bot. Ges., 68:331-344.
- _____, (1958) Klimadiagramm-Karte von Afrika, Bonn: Ludwig Röhrscheid, 27 p.
- West, Robert C. (1957) The Pacific Lowlands of Colombia, Louisiana State University Studies, Social Science Series, No. 8, 278 pp.

- Whittingham, H. E. (1965) A review of fire weather investigations in Australia. Fire Research Abstracts and Reviews, Nat. Acad. Sci., NRC, 7, No. 1:19-26
- Wilson, G. U. (1958a) A capability study of forecasts of maximum temperature, relative humidity, dew point, wind and precipitation in several states with special application to fire weather requirements, Austral. Meteorological Mag., Melbourne, 21:31-48.
- Wilson, G. U. (1958b) Some problems of estimating and predicting moisture content of forest and grass fuels, Fire Weather Confer., Melbourne, Australia, July 1953, Proc., No. 3, 9 pp.

Chapter IV

FIRE AND THE CULTURAL ENVIRONMENT

A. Introduction

The use of fire, together with the use of stone tools and the development of language, has probably been part of human culture since the time man first became distinguishable from other animals (Stewart, 1956). Definite archeological evidence exists that Peking man (Sinanthropus pekinensis) used fire in his caves. It is reasonable to suppose that primitive man very early discovered that fire was as capable of destroying vegetation as it was of cooking his meat. Yet it is likely that the earliest burning of vegetation by man was by accident rather than by design, as indicated by the widespread practices among primitive peoples of carrying fire with them in some slow-burning device, and of leaving campfires to smolder rather than extinguishing them.

Intentional burning is almost as ancient a practice as accidental burning. Fire clearance of forest, brush and grassland by present-day aboriginal peoples is a custom that has been carried on since prehistoric times. The comments of ancient writers, e.g., the Periplus of Hanno, the Carthaginian (circa 500 B.C.), lend support to this belief.

Intentional burning has been done for various purposes. Hunters use it to drive game, to clear bush so that game can be more easily seen, and to create an improved pasture to attract grazing animals. Gatherers use it to encourage the growth of desirable plants and to discourage the growth of others, and to smoke honey bees out of their nests. Farmers use it to clear and fertilize land for planting. Pastoral peoples use it to improve pasture for their flocks, to eliminate insects and snakes, and to discourage predators. The use of fire in war has been

referred to as early as 477 B.C. by Herodotus. Pyromania and arson, whether chronic or occasional, are common among all peoples. The conclusion is inescapable that burning has been man's earliest, most important, and most widespread means of clearing vegetation, and that its significance as an ecological factor must not be overlooked.

Although the same reasons for burning exist today as in the past, swidden cultivation¹ and burning to improve tropical pastures are now the most important. In 1957, it was estimated that 36 million square kilometers (14 million square miles)--about 25% of the earth's land surface--was under swidden cultivation, inhabited by about 200 million people at an average density of 5.4 per square kilometer (14 per square mile) (F.A.O. in Watters, 1960). Thus it is apparent that fire and its relation to patterns of human culture are highly significant geographical factors.

A two-part analysis will be used in this chapter to throw light on the relationships between fire and the cultural environment. First, the characteristics of the cultural environment that are responsible for fires will be considered. Special attention will be paid to the technology of the use of fire. Second, regional differences in demographic characteristics that relate to fire will be explained. The numbers, densities, and distribution of fire-using people will be considered.

¹Swidden cultivation is the term commonly used by anthropologists to refer to the form of agriculture "characterized by a rotation of fields rather than of crops, by short periods of cropping (one to three years) alternating with long fallow periods (up to twenty years or more, but often as short as six to eight years), by clearing by means of slash and burn, and by use of the hoe or digging stick, the plough only rarely being employed" (Pelzer in Watters, 1960). Shifting cultivation, fire farming, slash and burn agriculture, bush fallowing and many local terms are also in use. Swidden refers to the agricultural clearing

The man-land ratios and the effects of increasing population density will be discussed. The social and economic factors that are conducive to the use of fire will be analyzed. Some cultural trends that affect the use of fire will be pointed out. Specific examples from the literature will be presented to illustrate the major concepts.

B. Cultural Characteristics Relating to Fire.

The intimate relationship that has developed between man and fire has brought about a variety of cultural characteristics connected with fire. They range from the worship of fire as a symbol of the divine by the Zorcastrians, to the controlled use of fire as a source of heat energy by modern man. Human societies have developed a great diversity of practices and tools to kindle, use, and control fire. In this section those that are relevant to the problem of man-made fires in the tropical forests and grasslands will be considered, under the categories of site selection, providing a supply of fuel, lighting the fire, fire control, fire legislation, and cyclical patterns of burning. Examples will be presented from the literature to illustrate these practices.

1. Selection of a Site for Burning

The first step in the burning cycle is the selection of a site. Hunters, swidden cultivators, herdsman, foresters, forest gatherers, and honey collectors--each have different criteria to judge the suitability of a burning site. The religious or ritual aspect of site selection is often very important. Certain sites may be taboo, due to their use as cemeteries or their sacred character. The anthropological literature is rich in references to rituals that are used to propitiate the spirits. Pelzer (1945) mentions an example in southern Sulawesi, Indonesia, where the people send the village headman into the selected site to place betel leaves, lime, and a piece of areca nut under a tree, and to importune the spirits to show their approval by not scattering

the offering. After three days he returns, and if the offering is scattered a new site is chosen and the process is repeated. If the betel leaves are undisturbed, the male villagers eat a meal on the site. Then the land is divided among them and the betel leaf augury is repeated on each plot. If the offering is scattered three times, the head man gives the villager a share of his own land to use. Huke (1954) describes the choice of sites by the Kachin farmer in Burma. A fire is built on the ground at the first site, and a piece of specially chosen bamboo is put in the flames. When the air inside expands it splits the bamboo into small splinters, which are then divined by a priest. An unfavorable augury makes it necessary to repeat the process until a site is found where a good crop can be predicted.

The qualities of the land also have meaning to the swidden cultivator. Often the criteria are the result of millennia of trial and error, and represent a workable adaptation to the variable qualities of the soil, topography, drainage, and microclimate. The Kachin farmer described by Huke selects slope with southern exposure, so that adequate sunlight will reach the land. The farmer then stamps his bare foot on the ground, seeking a firm, not spongy surface. The proper cover of canes and bamboos must be present, since they indicate rich soil. Finally the farmer tastes the soil. If it has an oily flavor, the farmer will ask the village priest to perform his divination. Among the Barama River Caribs of British Guiana (J. Gillin, 1936) the primary criterion is good drainage. Their fields are frequently referred to as cassava hills. Another criterion is the soil, which must be "white dirt", a very sandy loam.

Perhaps the most important and most widely used criteria for site selection are the ecological ones. De Schlippe (1956) in his analysis of the Zande tribe of central Africa, describes a complex set of criteria based on vegetation and site. The type of vegetation reflects the intrinsic

fertility of the soil based on the following factors: climate; parent material; the soil forming process at work; the position of the site in the catenary succession from laterite crust to gently sloping red soils, steeply sloping yellow valley-side soils, and the clayey soils of the valley bottoms; the stage of regeneration of the abandoned field; and the effect of bush fires. The preferred site is on the gently sloping land, called pavuru-di, provided the vegetation is not a pyrophilous fire-resistant type that indicates frequent bush fires. Another favorite site is the mbudu-rago (soft place) or mbudu-sende (soft soil), a deep dark stoneless soil in well-drained depressions and on saddles. The stage of regeneration of the vegetation is indicated by the type of grass or shrub growing on the site. The Zande make use of their knowledge of the cycle of regeneration to plant the crop combinations that will have the best chance of succeeding.

Another important consideration is the spatial relationships of the swidden site. Baker (1965), in his study of the climatically transitional Walawe Ganga Basin of southern Ceylon, showed that the location of chena (swidden) sites is influenced by: proximity of paddy growing villages with tanks; proximity to roads, paths or tracks through the forests; and proximity to the heavily populated wet zone. For chenas used to grow illegal marijuana, isolation, rather than proximity, is the important criterion (See PLATE 23).

The criteria used by foresters for selecting a location for burning are different from those used by swidden cultivators. A. G. McArthur (1962) points out four main classes of site in Australian forests. They are: 1) areas where logging operations have been concluded, and it is desired to dispose of the tops and branches; 2) areas of catastrophe, such as blowdown or insect attack, and it is desired to reduce fuel accumulation; 3) areas where felled debris must be disposed of before exotic plantations can be established; and 4) most important, green timber areas where

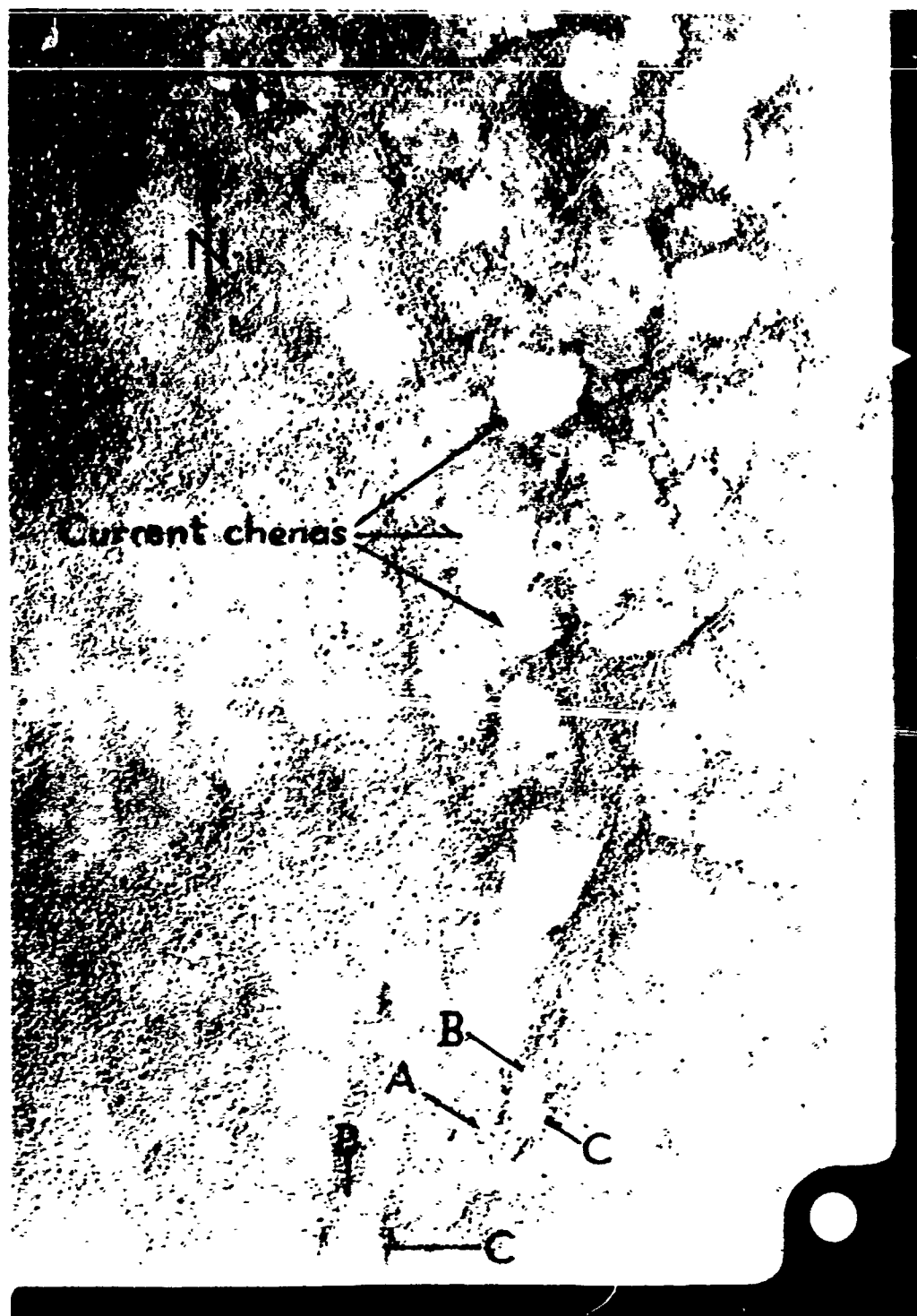


PLATE 23: Chenas (swiddens) in southern Ceylon, Lat. 6° 20' N., Long. 80° 57' E. Stage of regrowth shown by tone of photo, from light (currently in use) to dark. A-village; B-tank; C-paddy field. (Photo courtesy S. Baker).

fuel supply needs to be reduced (control burning). The ideal site is a "compartment" or group of compartments, or an area of 100-900 acres surrounded by a trafficable road or trail. The area should be sufficiently small so as to be completed in one operation.

Burning by pastoral peoples takes into consideration the variability of rainfall onset and the density of the animal population. C. M. Davis (1959) observed that stockmen in northern Australia burned late in the dry season in strips or patches, so that not all of the dry grass forage would be destroyed before the rains begin. They also sought to protect the cattle station by burning a fire break.

The native herders in Africa make regular use of fire to clear old dry grasses and encourage a flush of new shoots. At the same time they make it easier to protect the cattle from snakes, predators, and insects. A great variety of sites may be chosen. The prevailing practice of migratory Dodos herders in the Karamoja district of northeastern Uganda is to burn off the grasses in advance of their annual migration from the eastern to the western parts of the district. Peoples who do not migrate, such as the Acholi of northern Uganda, will burn off the upland grass in the dry season while their cattle graze in the grass swamps, where the grazing remains adequate during the dry season (Parsons 1960a, 1950b).

Burning sites may be as small as the fraction of a hectare used by a swidden cultivator or they may be very large, such as when they are used as a barrier against tsetse flies. Cockbill (1955) describes a strip of land 3.2 to 5.0 kilometers (2 to 3 miles) wide and 64 kilometers (40 miles) long in Southern Rhodesia on the border with Mozambique. This strip is cleared and burned. It acts as a barrier to certain tsetse species, thus permitting commercial cattle grazing in the southeastern part of the country. Elsewhere in Southern Rhodesia such a barrier is not effective against dominant tsetse species. Since wild game is often an

important host for the trypanosome parasite, the grass is burned to make hunting of game easier.

The angle of slope of the land selected for burning will naturally vary according to the prevailing topographic conditions in an area. Level land is normally preferred by the swidden cultivator, but in the more densely populated parts of Southeast Asia, he has been forced into the hills by the wet rice cultivators. The "chimney effect" in which a fire burns fiercely and rapidly upslope, is used by the swidden cultivator. Oración (1963) describes how the Bukidnons of Negros island in the Philippines light their fires at the bottom of a slope. Overholt (1963-64) observed a similar practice on Panay. Conklin (1957) in a study of the Hanunóo of Mindoro island, shows a photograph of a swidden plot on fire, where the line of flames is moving parallel to the angle of slope. This method combines the intense heat of the chimney effect with slower horizontal movement of the fire front. On the other hand, Ward (1960) describes a wet zone hill village on Vitilevu in the Fiji Islands, in which the top of a ridge is cleared, burned, and planted with taro and yaqona (Piper methysticum). As the taro is harvested, the garden is gradually extended down the slope.

The selection of a site for burning thus seems to be dependent on a variety of factors, and it is difficult to generalize about them. They include the magical qualities of the land; the traditional ecological judgement of the cultivator or herder; the use to which the land is to be put, whether for hunting, cultivation, forestry, or grazing; the seasonal pattern of rainfall; and the extent of regeneration of the vegetation cover from previous burns. In each area these and other factors make a unique combination.

2. Providing a Supply of Fuel

After selecting a site, the next stage in the burning sequence is the provision of a supply of dry fuel. A variety of factors influence the geographic distribution of techniques used to provide the fuel. Among the most important

are climate, the type of vegetation, the purpose of burning, the amount of labor available, the tools, techniques and cultural practices of the people doing the burning.

The most important climatic factor is the length and severity of the dry season. If the dry season is well-defined and fairly severe, many forms of vegetation can be ignited easily without special preparation by man. If the dry season is short or non-existent, and the area is forested, it is necessary for man to cut or otherwise prepare the vegetation so that it may dry out for burning.

The purpose of burning, the cultural practices, tools and techniques, and the labor supply available are usually closely related to the nature of the cultural group occupying the land. Swidden farmers may clear the land communally or by individual families. The burning of grassland may be to prevent bush encroachment on lands pastured by commercial stockmen, or to secure a flush of new grass on lands pastured by migratory herders. The piling of felled vegetation may be to provide more fertilizing ash, or to roster a more intense fire when once ignited, or for both of these purposes.

The technique of clearing tropical forests has certain features in common wherever it is found. A division of labor between the sexes usually exists, in which the felling of large trees is the work of men, while small trees and brush are cut by the women. The individual family may clear its own plot, or the community may work in common. Huke (1954), describing a North Burma Kachin Village, says: "Every family clears its own plot of undergrowth, hanging vines, and small trees. This takes about a month of hard work by the entire family. The largest trees are felled by all of the village men working together, one day of community labor being devoted to each family's taungya [swidden]."

Primitive and advanced cultures both employ various devices to deal with large trees. For example, the Tobelorese people (Hueting, 1906) of Halmahera, Indonesia, and the

plantation rubber workers of Malaya (Gawthorn, 1962) both employ a scaffold erected 4-6 meters high above the flaring buttresses of a large tree. This permits them to cut through it at a place of smaller diameter. Frequently nearby smaller trees are cut part way through, and the large tree takes them down when it falls. Trees too large to be felled may be killed by cutting a ring or girdle through the bark and cambium layer, or by building a fire around the base of the tree. When the tree dies, the leaves fall, permitting the sun to reach the soil below the branches. Generally the smaller trees and undergrowth are cleared first, so as to permit access to the large trees. White (1945), referring to clearing for plantations in the Ceylon Dry Zone, considers that this also helps to pack the jungle down and get a better burn.

The forest may or may not be cleared thoroughly. White (above) describes a method of reducing the cost of removing stumps by cutting the main lateral roots of very large trees a short distance from the base. At the same time the main stem is cut just enough to cause a slight bending over of the trunk. Then the whole tree will come down with much of the tap root. The remaining stumps are dug out by hand. Such thorough clearing is not usual among swidden cultivators. PLATES 24 and 25 illustrate an incompletely cleared swidden plot in British Guiana, where cassava roots are planted in the spaces between the partly burned logs.

There are other techniques of dealing with large trees that do not kill the tree. These are pollarding, or removing all the branches from the trunk; and trimming, or removing only the leafy branches of the trees. These practices permit rapid regrowth of the tree after the field is abandoned.

3. Lighting the Fire

Once a supply of dry fuel has been provided, the next step is to set it on fire. In most cases there is no problem in doing this. However, where the microclimate is humid and a long dry season does not exist, or where the



PLATE 24: A clearing in fairly mature second growth moist semideciduous forest near Aishalton, Rupununi District, Guyana, located on the savanna/forest boundary between the Rupununi R. and the Illiwa R.
(Photo by T. L. Hills)



PLATE 25: Cassava roots (awaiting planting) leaning against charred logs near Aishalton, Guyana. Note density of unburned timber. Compare with "clean burn" in PLATE
(Photo by T. L. Hills)

particular combination of fuels is intractable, or where specific limitations of area, shape, or quality of burn exist, it becomes necessary to take special measures.

The techniques used by the rubber planters of Malaya to set newly felled jungle on fire are illustrative of areas having a tropical rainforest vegetation with only a short, relatively dry season, and fuels that are difficult to set on fire. Gawthorn (1962) recommends that the burn should take place before the leaves drop from the felled trees, but not less than seven weeks after the last tree has been felled. The fire should be started about 11:30 A.M., after the dew has evaporated. A recommendation from another study of the same area is that firing is more likely to be successful after three days without rain and when there is light wind. Two methods of lighting are advocated. One is to light fires at frequent intervals around the perimeter of the clearing, and allow the fire to work inward. Another is to cut rough tracks through the felled jungle at intervals of five to ten chains (120 to 240 meters), and then send a gang of laborers through the clearing in line abreast formation, lighting fires as they proceed against the wind.

Sanderson, Menon, and Ganapathy (1962) point out how difficult it is to set fire to the Malayan forest, however, and they recommend the use of special combustible materials and time fuses, as shown in the following quotation.

For various reasons there is never any certainty about the success of a burn. Often during a burn the laborers setting fire to the felled jungle are diverted, for one reason or another, from their normal courses through the area. The wind may change or there may be natural obstacles or the people to the left or right may have advanced too quickly. There is always some chance of individuals or groups of individuals being cut off and as a result patches of felled jungle are left unburned or only partially burned.

Combustibles and Fire points.--Normally no action is taken to help felled jungle to burn. The fire-setters advance so quickly that they do not have time to insure that the ignited points continue to burn and spread. It would obviously be an advantage if, at various points throughout the felled area, combustibles could be laid down beforehand so as to make certain that a series of really large fires are started.

Four main types of combustibles have been used: 1) pieces of old tyres; 2) scraps of foam rubber; 3) pieces of sacking soaked in damar oil [damar: a copallike resin chiefly from dipterocarpaceous trees of southern Asia, esp. Malaya and Sumatra, much used for making colorless varnish (Amer. Coll. Dict.)]; 4) sawdust and damar oil.

Various types and combinations of fire points (preset combustibles) have been tried. A typical fire point now consists of the following: one piece of sacking soaked in damar oil, one or two pieces of foam rubber scrap, and one piece of old rubber tyre. Advantage is taken of a point where timber, both large and small, is denser than average. ... On the average, fire points are laid down at a density of thirty per acre.

The [time] fuse consists of a Chinese joss stick half an inch in diameter mounted on a sliver of wood or bamboo which enables it to be stuck in the ground. The joss stick smoulders at the rate of approx. 10 inches per hour. At the bottom of the joss stick a jacket of five matches with heads upwards and all at the same level are secured to the joss stick by a 3 X 3 inch piece of sacking soaked in damar oil. The heads of the matches are just clear of the oil soaked sacking. ...With fuses, fire points are essential. All fire points ignite simultaneously, thus increasing the chances of a good burn. ... Burnings of 200-400 acres [81 to 162 hectares] are ideal (Sanderson, Menon, and Ganapathy, 1962, pp. 109-112).

A similar use of time fuses has been observed in Senegal, where rivalries between grazing and farming tribes, and between individual natives, have been the occasion for arson. A mixture of chopped straw, dry manure, and other vegetable matter is left smouldering, and after a time a fire begins and spreads.

A grid system of spot fires, one chain by one chain to ten chains by ten chains (24 X 24 meters to 240 X 240 meters) has been prescribed for control burning in Australian eucalypt forests by McArthur (1962). One objective of the system is to prevent the joining of spot fires. This reduces the possibility of damage to the trees resulting from excessively hot fires. Another technique is the use of a jeep-mounted flame thrower moving through trails cut through the forest.

The means employed by native peoples vary from place to place and from group to group. A torch of some kind is frequently used, as among the Hanunóo of Mindoro, who employ a torch of dried, cracked bamboo (Conklin, 1957). African hunters trail a lighted grass rope around the area selected for burning to flush out the game animals.

Accidental fires may be started in the steppes and savannas during the dry season by many different means. Honey gatherers' fires, travelers' fires, native cooking fires, muzzle loading muskets, housewives and children carrying live coals from one village to another--these and many other means can cause a conflagration.

4. Fire Control

In most parts of the tropical world, the subject of fire control is in the initial stages of planning and implementation. Policies and methods employed in controlling fire are usually adaptations of legislation and control practices successfully employed in middle latitudes. The increasing concern of governmental agencies, both local and national, reflects a greater awareness of the need to protect valuable forest and grassland resources. As commercial exploitation of these resources expands, there is little doubt that more stringent fire control legislation and enforcement will occur. The concern of many who have studied aspects of the tropical environment affected by fire is that adequate fire control may come too late to parts of the tropics, particularly Sub-Saharan Africa.

Methods of fire control include intensive fire lookout networks and modern fire suppression techniques and equipment, control burning to reduce fire hazard and fire severity by reducing the accumulation of fuels, and preparation of fire breaks. Control burning and use of fire breaks represent the most widely applied methods of fire control, regardless of the technological level of those using fire.

Although the technological level of native peoples is in most cases very low, they nevertheless have a variety of methods to control fires. Most of them are concerned with limiting fire spread and with reducing the effects of fire on vegetation to be spared. Among the pastoral Fulani of Ferlo in Senegal, a seasonal migration used to take place, wherein the tribe and its animals moved in the dry season to permanent sources of water. For a few members who stayed behind it was necessary to provide protection against uncontrolled brush fires. This was done by burning a radial-concentric firebreak 2 to 3 kilometers in radius (République du Sénégal, n.d.).

Among the Hanunóo Conklin observed similar protective fire paths, but in this case they were cleared by hand to limit the spread of fire when a swidden of felled trees and brush was burned. He also noted that the slashed vegetation was not allowed to cover places where root crops had been planted. These can survive the burn when protected by green banana sheaths. Neither was fuel piled around individually-owned trees that he calls "semi-domesticates." In northern Burma the Kachins rely on the perennially moist character of the forest to prevent the escape of fires (Huke, 1954). Allan (1916) describes how men, women and children armed themselves with leafy branches to beat out runaway fires in a taungya in bamboo land in Burma.

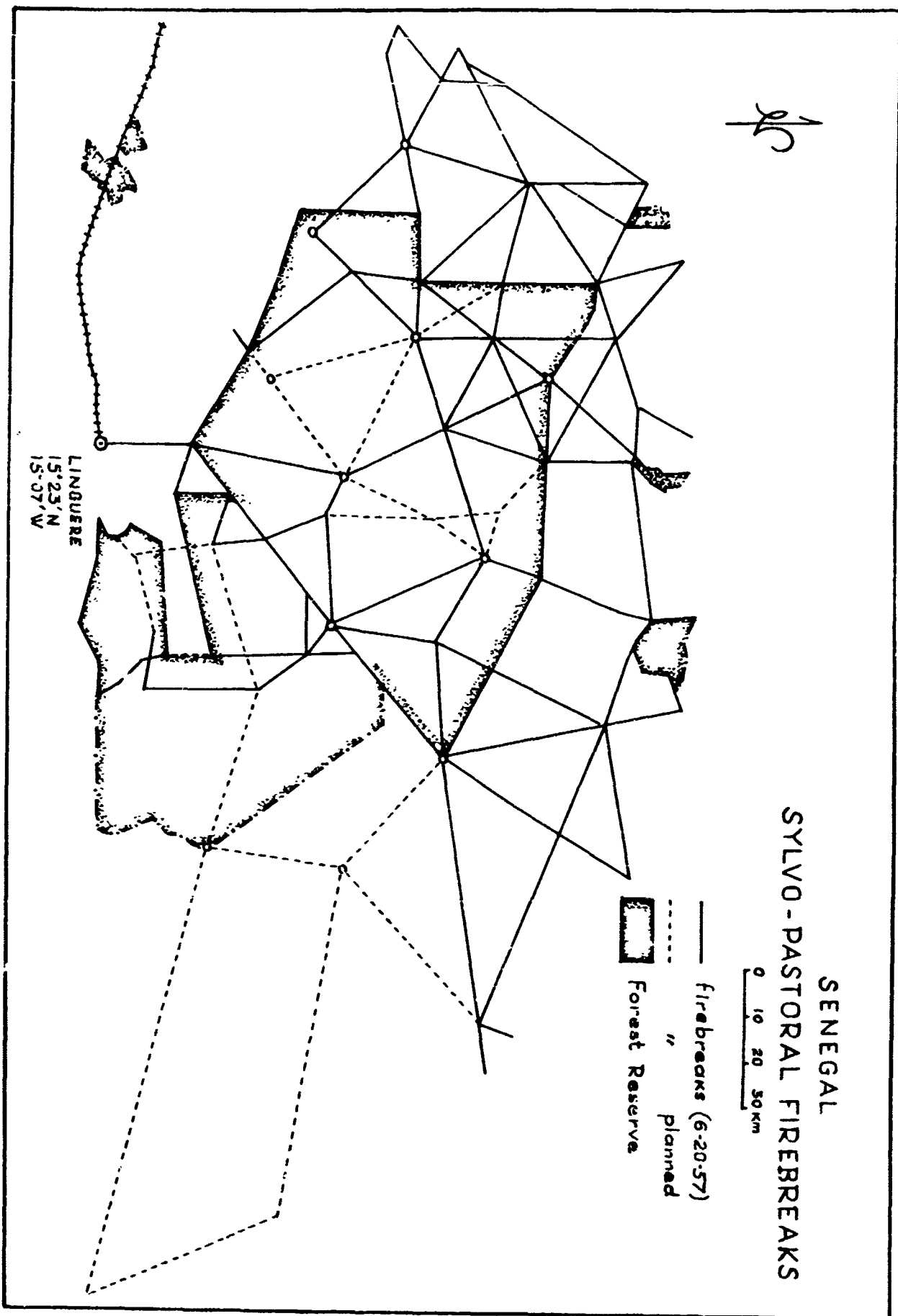
The "sylvo-pastoral" region of Senegal, is a good example of a tropical grass and wooded area subject to modern fire control methods. Located in the central and northwestern part of Senegal, the region covers about 40 per cent of its

territory (Giffard, 1965). The region is partitioned by a network of firebreaks extending over 3,400 km. and having six to nine meters width (Map 2). The firebreaks also serve as routes of communication. The area is rainless during six months of the year. Deep wells (200-300 meters) have been constructed to provide water to herders and their animals during the winter. The network of firebreaks forms a series of triangles and polygons which enclose areas varying from 6 to 3,064 sq. km. In the classified sylvo-pastoral forest reserves, where the network is densest, the triangles vary from 48 to 450 sq km. The length of the firebreaks--completed and planned--ranges from 2 to 86 km. and averages 30 km.

It is questionable whether the firebreaks actually are able to prevent the spread of wild fire pushed by a strong wind through an area well supplied with fuel. It is not difficult for burning embers to be blown the 6 to 9 m. across them. Indeed, it has been estimated that under average conditions of fuel supply, air humidity, and wind force, there is a 50 per cent chance of a fire crossing a cleared strip 6.5 meters wide.

Perhaps the greatest value of the firebreaks is as routes making the region accessible to fire-fighting apparatus. From November to May every year operations are undertaken against fires. Use of modern equipment permits three procedures to be employed: 1, the direct projection of water into the flames by means of fire hoses; 2) the spraying of water from sprayers mounted on tractors; and 3) atomization and fogging with high pressure fog apparatus. The existence of deep wells makes it possible to refill water tanks conveniently.

A comprehensive study of the problem of veld fires in Southern Rhodesia, emphasizing the practical aspects, has been made and is a good example of fire control problems (Gammon, 1962). The sources of uncontrolled veld fires and suggested preventive measures, the establishment and construction of



Map 2

"fireguards" (firebreaks), the kinds and uses of fire fighting equipment, controlled burning, and fire control legislation are explained in detail and evaluated. Much of Gammon's article deals with the problem of fireguards, which are considered the most important means of defense against uncontrolled fires. It must be emphasized, however, that fireguards alone are inadequate protection. They serve as a base from which to actively fight a fire, and as a means of control in intentional burning.

Gammon emphasizes the need to take advantage of streams, roads, bare rock and other features in selecting sites for fireguards. Where there is a prevailing wind, it is desirable to align them in a direction slightly oblique to the wind, to reduce the chances of a fire striking the fireguard on a broad front. In rolling country they should follow the ridges, and where there is both woodland and grassland, they should follow line of contact. The width of the fireguard should be from 10 m. either side of a common boundary, up to as much as 65 meters, depending on the severity of the conditions.

Fireguards vary in their sizes and type of construction. The simplest is a cleaned strip or "tracer", either plowed, disk harrowed, or hoed, until free of vegetation. A refinement of this is a cleared and rough-graded "fire track" along fence lines which also serves as a road. The most common form is the burnt fireguard, a strip burnt between two "safety strips" which may be plow furrows, watered strips, mown strips, or tracers. Where the fireguard is wide and the land is valuable, the fireguard becomes a "buffer strip" if it is used for non-combustible trees, shrubs, or crops. Finally there is the "boundary paddock", a long, narrow, fenced pasture bounding the property which is heavily stocked with cattle in the beginning of the dry season, so that the grass is eaten to the ground. In the Transvaal the European farmers allocate such strips as farm land to their laborers.

A variation of the boundary paddock is the practice of spraying a strip of grass along the edge of a field with a mixture of urea and molasses, which is attractive to the cattle, so that it is grazed to the ground. This saves the cost of building an additional fence.

The choice of fire fighting equipment in Southern Rhodesia is influenced by the availability of African labor. The use of native beaters is a very important aspect of early control. A five foot stick to which a flexible, flat, non-inflammable paddle is attached is recommended. Leather, tractor tubing, and fire hose are excellent. Mention is also made of spraying and fogging equipment, manual and powered by tractor power takeoffs.

Gammon's advice concerning fire fighting methods is concrete.

In fighting a veld fire one must first decide whether to make a direct attack on it, wait for it to reach a fireguard, or backburn from a fireguard. In heavy grass with any wind it is virtually impossible to beat out a fire except at a fireguard. With little wind and a light grass cover... it may be worth making a direct attack on the fire, particularly if spray equipment can be used and if the fire still has a long way to go to reach the fireguard.... Veld fires generally take up a tongue-shape pattern, travelling in the direction of the wind, with a more or less gradual spread to either side of the line of travel. The basic principle in tackling any fire, therefore, should be to make flanking attacks from either side, driving it into an ever-narrowing wedge (Fig.16).

If one is sufficiently sure that the fire can be beaten out at the fireguard this can be done, but generally backburning is preferable. Backburning can be described as the deliberate firing of a strip of veld at a fireguard in such a way as to meet an oncoming fire. It has been said that the essential feature of back burning is to time the operation so that advantage can be taken of the up-draught created by the main fire, so that the back-burn fire is sucked back into the main fire which is thus burnt out. If, however, backburning has to be done along a wide front, which is usually the

case, it will be dangerous to wait until the main fire is close enough for the effect of its updraught to be experienced. It is more advisable to start burning well in advance of the main fire. The back-burn fire will burn slowly upwind, till the main fire is fairly close, and then will be drawn rapidly back into it (Gammon, 1962, p. 136).

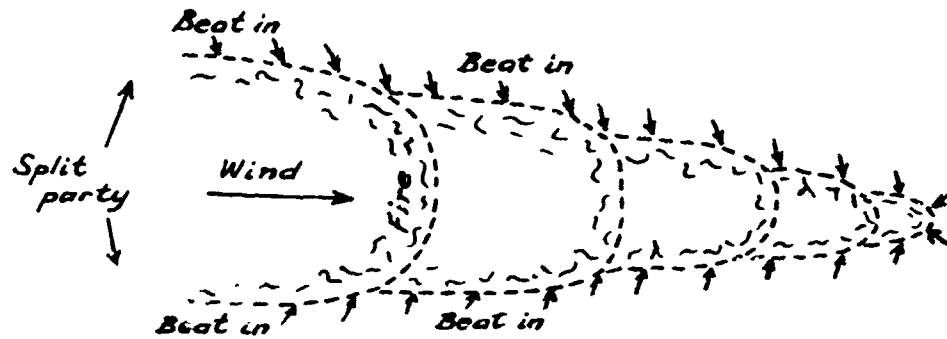


Fig. 16. Techniques Employed to Fight Grass Fires in the Absence of Modern Equipment, Southern Rhodesia.

After Gammon, 1962

Comprehensive legislation to regulate the setting and control of fires exists in Southern Rhodesia. The laws reflect the social and economic characteristics of the country. They take note of the need to burn for pasture improvement and for forest protection. They require notification of neighbors and the police before burning is begun. They require the cooperative efforts of all persons to prevent the spread of dangerous fires. They establish the right and responsibility of the individual to take action against fires deemed dangerous to life and property, and his authority to call upon others for assistance. They authorize the government to compel property owners to take protective measures, including fireguards thirty feet wide along common property boundaries.

Gammon's conclusions regarding veld fires in Southern Rhodesia are discouraging. He feels that the landowners have not been sufficiently convinced of the benefits of fireguards, that the legislation has not been adequately enforced, and that the estimated six million acres (2.4 million hectares) burned by uncontrolled veld fires in 1959 could have a seriously detrimental effect on the problem of preventing bush encroachment in veld management.

5. Cyclical Patterns of Burning

One characteristic of most intentional burning in tropical forests and grasslands is its cyclical nature. Non-cyclical or sporadic fires may be accidental or intentional, and they may cause considerable damage to life and property. However, they are not predictable, except in terms of probability. The cyclical patterns of burning, on the other hand, are part of some repetitive annual or longer-term cycle of activities. They are capable of being studied from the standpoint of their roles in man's economic life and their relation to the vegetation cover.

A distinction should be made between the annual cycle of burning and the perennial cycle of burning. The annual cycle refers to a pattern of activities, including burning, that is related to the seasons. The perennial cycle refers to a pattern in which a site is burned, and then a sequence of activities takes place leading to another burning of the same site after the passage of more than one year.

a. The annual cycle of burning.--This pattern of burning is typical of the swidden cultivators and tropical cattle-keeping peoples. In order to depict the complexity and variety of the practices followed by swidden cultivators, the studies of Miracle (1964) and Corklin (1957b) are discussed below.

The study of traditional agricultural methods in the Congo Basin by Miracle illustrates the annual or short-term cycles used by primitive African cultivators in tropical forest, woodland, and savanna environments. Miracle disting-

uishes six major types of land preparation, all using fire to help clear the vegetation or to reduce it to fertilizing ash. Compare the map depicting the location and distribution of these types with the map of tribal groups for essentially the same area in Central Africa (Maps 3 and 4). Note the diversity in time of burning due to cultural tradition. Compare these maps with Map 6 in Chapter V. (See Chapter V, page 186 for explanation of symbols.)

The most widespread system is type 1--cut, burn, and plant--in which the vegetation is felled near the end of the dry season, allowed to dry, and then burned just before the rains begin. There are ten subdivisions of this system, based on the amount of cutting and burning and the extent of cleaning and leveling operations. This system is found in forest, woodland, and savanna.

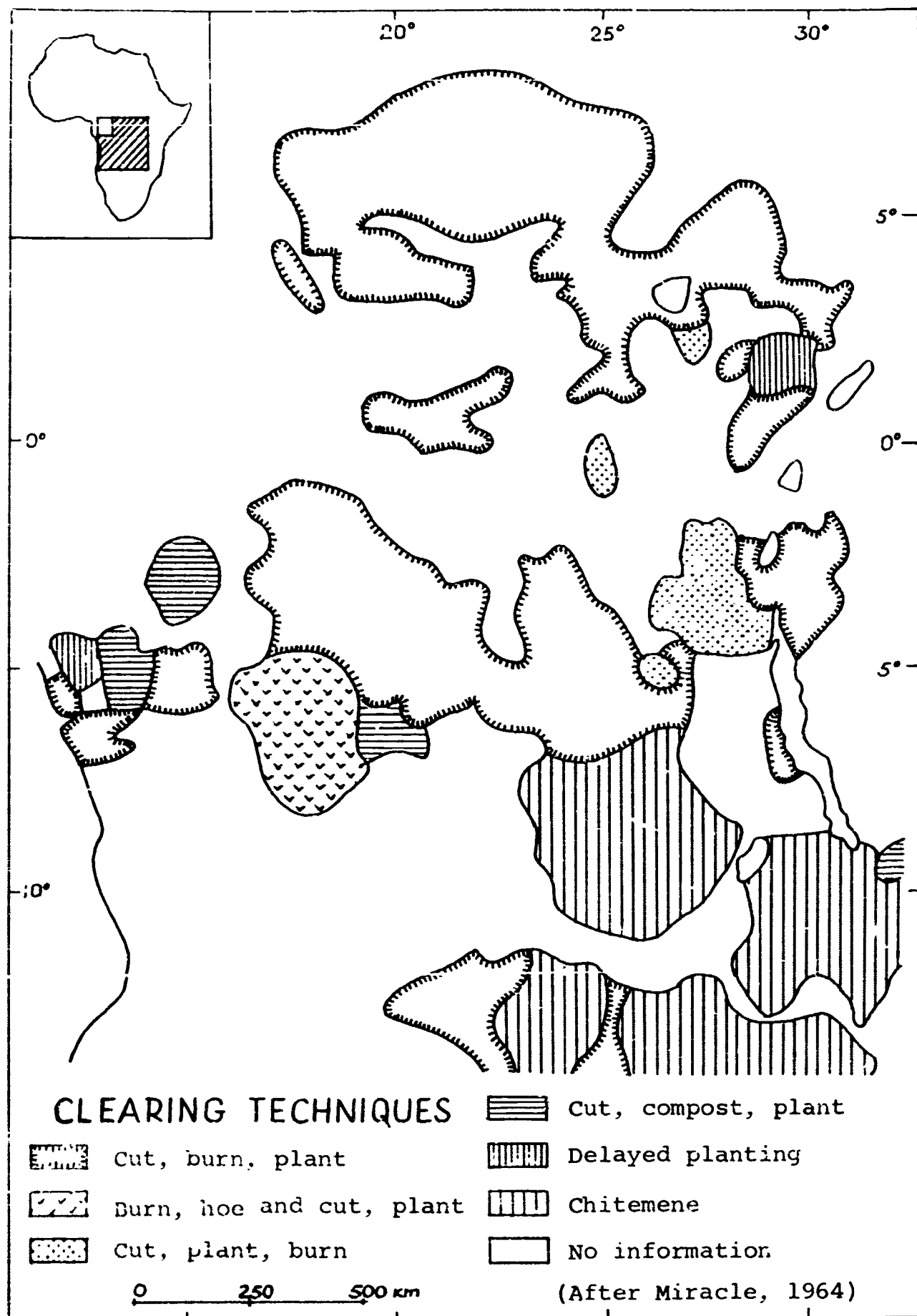
The type 2 system--burn, hoe and cut, plant--is found only in savanna areas. The savannas are burned in the dry season, and then the ashes and remaining refuse are hoed into large mounds about 35 cm. high.

The type 3 system--cut, plant, burn (forest)--is found in the tropical forest or "derived savanna." The burn takes place after banana, plantain, or manioc has been planted, but the crops are not damaged by the fire.

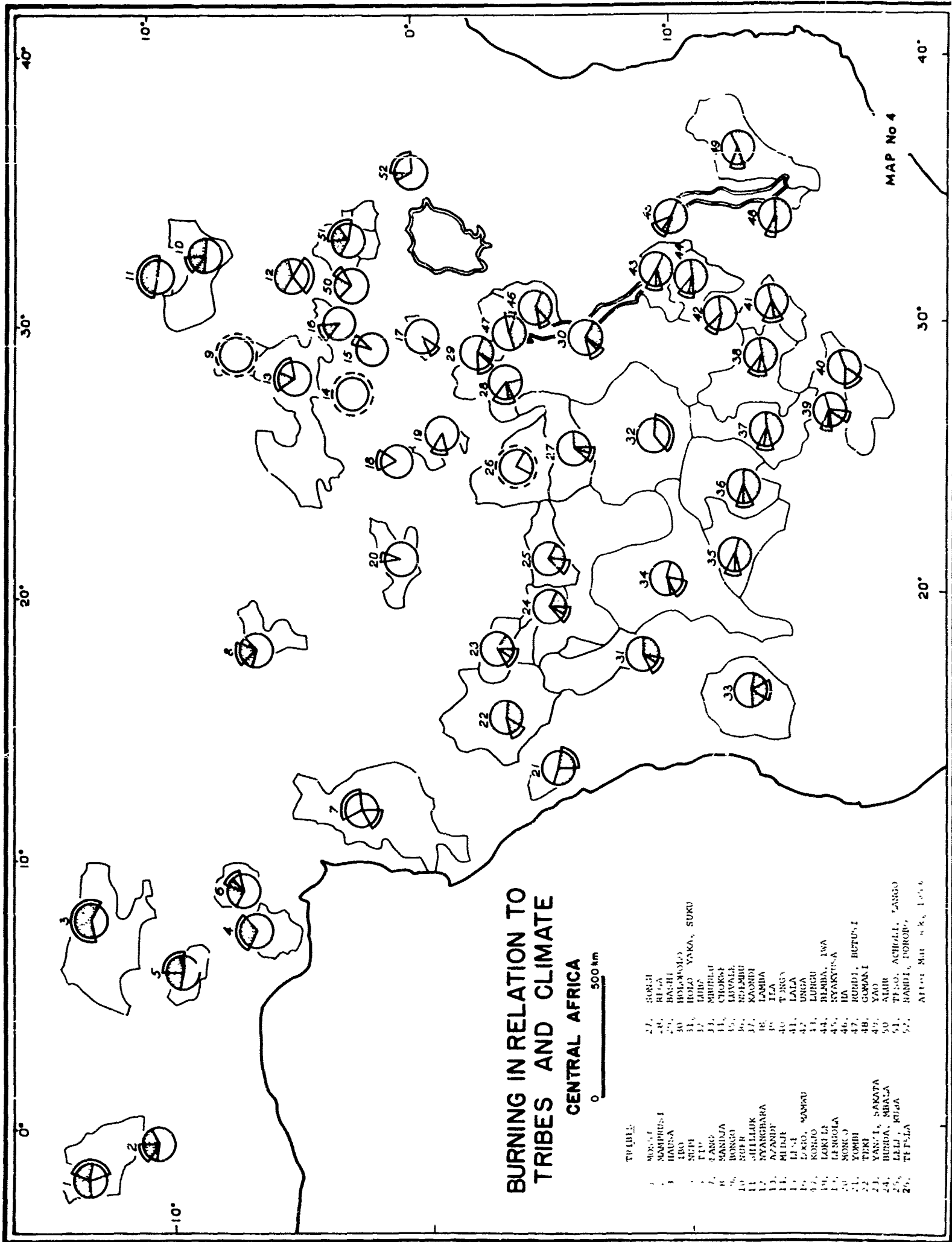
The type 4 system--cut, bury refuse in mounds, plant--is a system that involves a form of composting. On the Koukouya Plateau in Congo (Brazzaville) the Teke people cut and pile the grass, cover it with soil, and then ignite the mounds.

The type 5 system--cut, wait one season, plant (forest)--is a system found in the forest and park-like savanna near the mouth of the Congo River, and also in a similar area in the northeastern part of Congo Basin.

The type 6 system--cut, add extra wood, burn, plant, hoe--is a system commonly referred to as chitamene. Its main



Map 3



feature is the cutting of vegetation from an area from five to twenty-times larger than the area to be planted. This technique provides a hotter fire and a greater amount of fertilizing ash. Among the other studies of peoples using chitemene are Richard's work on the Bemba of Zambia (1939) and Trapnell and Clothier's (1937) study of northwestern Zambia. The Bemba cut branches from an area up to six times as large as the area to be planted, pile the wood to a height of about 65 cm. in a large circle, and burn it after a period of drying. Other tribes, such as the Lala of Zambia, use several small circles, and cut vegetation from an area fourteen times larger than the planted area.

The annual cycle of burning is part of a complex sequence of inter-related agricultural operations, as revealed by the following list of stages in the Hanunóo agricultural cycle (adapted from Conklin, 1957b).

1. Garamasun Land selected as a site for clearing. Before planting the site is called parayan.
2. Gamasun A selected site in which the undergrowth has been slashed in preparation for the heavy work of felling the large trees.
3. Puklid The clearing after completion of felling.
4. Tutud The burned off clearing.
5. Tanman The planted clearing.
6. Dayamihan The clearing after rice has been harvested.
7. Lumun bag'uhan The almost completely harvested clearing in which pigs may be allowed to forage if there has been no supplementary planting.
8. Lumun da'an Trees and other long-persisting plants, such as bananas, are planted before the clearing is left for the long fallow (see below).
9. Ginaru' Low-growth fallow. During this and the fallowing period of fallow, the old clearing will continue to be visited for whatever produce it may yield, in the way of fruits, roots, etc.

10. Talun The clearing has largely been reclaimed by tree growth.

It is apparent that the first eight stages in the above cycle are parts of the annual cycle that the Hanunóo follow, clearing a new field each year for their rice planting. The last two stages are part of the perennial cycle, in which the forest regenerates itself. Thus the overlap between the annual and perennial cycles is evident.

The annual cycle of burning may also be seen in the practices of African and South American herders, who burn off the savannas each year in order to provide a flush of new growth for their livestock. This procedure has been noted in numerous publications, e.g., Tamayo (1962), Bates (1948), Aitken (1964). It is used by commercial livestock raisers as well as native subsistence grazers. Among the Swazi of Swaziland, for example, grazing is combined with agriculture. Part of the grazing land is burned every autumn, while the remainder is used for winter forage (Marwick, 1940). A high point in the annual grazing cycle of the Nyakyusa of Tanzania, is the burning of pasture during a brief dry period in October or November (Wilson, 1938).

Adoption of native methods of annual range burning by European commercial graziers, is mentioned by Stocker (n.d.) for northern Australia, and by Botha (1945a) for the eastern Transvaal. Interestingly, experimental evidence is accumulating that leads to the conclusion that burning cycles, including resting periods and controlled grazing, of several years duration are highly desirable, and are much less detrimental to quality and quantity of graze than annual burning (Scott, 1952).

There is another aspect to the annual cycle. This is the interconnection between the agricultural work associated with the clearing and cropping of the swidden site, and the other work that provides food or cash income between harvests. The agricultural year of the Semai Senoi aboriginals of Malaya reveals this interconnection (see Table 12).

TABLE 12
THE SEMAI SENOI AGRICULTURAL YEAR

Approximate Period	Agricultural Work	Other Work	Main Sources of Food	Subsidiary Source of Food
i April - May	New ladang site selected and initial area--two to three acres--felled.	Some collection of jungle produce bamboos rotans and jungle gums.	Tapioca from last years ladang.	Purchased food from sale of jungle produce. Animals trapped and snared, fish, jungle roots.
ii May - June	Initial site burnt off and planted. (Usually maize, some tapioca and bananas). Felling of main ladang commenced.	Temporary shelters erected followed by new houses.	Do.	Do.
iii July-August	Main ladang burnt off and planted. General order: (i) Hill padi (ii) Tapioca (iii) Maize, keladi and sweet potatoes.	Fruit season. perah nut and Petai most important.	Do. plus jungle fruits.	Do. plus sale of jungle fruits particularly Petai and acorns.
iv. September-October	weeding	Repair of fish traps Fishing.	Do. plus first maize crop	End of Fruit season. Rather less collection of jungle produce.
v. November-December	Harvest of main padi crop.	Durian season	Padi	Do.
vi. January - March		Fishing and collection of jungle produce.	Padi and new tapioca, keladi, sweet potatoes, etc.	Sale of jungle produce.

(After Williams-Hunt, 1952)

Annual burning may also be done for other purposes than agriculture. In Laos it is a common practice to light fires during the passage of migratory birds in order to make them converge towards the nets (Turbang, 1961). Burning for hunting may have an annual cycle if it is associated with a regular period when other sources of food are unavailable, such as during growing seasons. In Brazil an annual religious festival, the Fiesta juanina (St. John's Day) in June is marked by the adoration of fire, and frequent fire break out (Gonzales Silva, 1957). Burning to clear snakes from rural paths will be more likely to take place during the seasons when travel is frequent, such as when the harvest is being brought to the towns for sale.

The time of annual burning varies widely in different areas of the world. The seasonal distribution of precipitation, the purpose for which burning is done, and the cultural patterns of the population are significant factors influencing the time of burning. Burning may occur as soon as the fuel has become sufficiently dry. The usual practice among farmers and herders is to burn as late in the dry season as possible, before the first rains of wet season. For Africa, South and Southeast Asia, and Latin America the dry season and burning period for numerous stations in various vegetation zones has been mapped (Maps 1 to 5).

In some areas a double minimum of rainfall makes it possible to burn twice a year, as shown for Ambam, Cameroon (Station No. 38), and as reported for Colombia (Suarez de Castro, 1953). Even brief periods of relatively less rainfall in areas of humid tropical forest may permit the burning of felled vegetation.

Among some forest cultivators, such as the Tim and Kamuk peoples of the northeastern mountains of Thailand, the initial burning is followed by later burnings to get rid of the remaining charred stumps and logs (Credner, 1935). A burned swidden plot in Guatemala illustrates a "good, clean"

burn, in which the maximum ash has been produced and nearly all weeds have been killed (PLATE 26).

The practice of "early burning" (control burning) has been widely adopted by the forest departments of African countries. Burning early in the dry season is preferable to late burning because the flames are less intense and less destructive to the trees and seedlings, yet they reduce the accumulation of grass and undesirable brush from the forest land.

b. The perennial cycle of burning.--The annual cycle of burning described above is often a stage in a long term process by which the regeneration of the forest makes it possible for the swidden cultivator to return to a previously burned site after a period of years and repeat the annual cycle. This process is referred to here as the perennial cycle of burning. The term may also be useful to describe situations such as those in which control burning is used at intervals of greater than one year, as part of a program of forest or grassland management.

In Africa the use of fire by commercial cattle graziers has been recognized as a permitted, even desirable, practice to prevent bush encroachment on grasslands. "The intelligent and systematic use of fire in a properly designed system of veld management is the only means whereby the grazier can maintain the productivity of his grazing land" (West, 1958, p. 412). Whereas the forester prefers to burn early in the dry season to reduce the intensity of the flames and preserve the trees, the grazier requires a late burn so that the intense fire will do the greatest damage to the grass. A minimum interval of four years between burns and a rest period before and after burning are recommended by West (1958).

Pelzer (1945, p. 16) has succinctly described the perennial cycle of swidden cultivation in the tropical forest in the following terms:



PLATE 26: Burned second growth forest, eastern Guatemala, near Lake Izabal. A good clean burn, since nearly all weeds have been killed and maximum ash has been produced. (Photo by H. Popenoe).

... the shifting swidden cultivator does not use the same piece of land every year; instead, he kills or cuts down at regular intervals--every year, every other year, or every third year--the trees of a small forest patch. ...As forest land is generally free from weeds or grasses and the soil is usually rich in humus and well supplied with the ash of burned plant matter after clearing, it produces a very good, even excellent first harvest; the second harvest begins to show a decline in yield, and thereafter the returns diminish rapidly. ...for parts of the Lampoeng Districts ... a ladang (swidden) will produce from 15 to 25 quintals of rice in the first year and approximately 5 in the second year. Grasses and weeds invade the clearing. Rather than battle these, the peasant abandons his old ladang and cuts and burns a new patch of forest. The old plot reverts, under favorable conditions, to second-growth forest, ...and is not cleared again for a period, the length of which may vary from 8 to 15 years, or more.

There are several significant variables in the swidden cycle described above. One is the number of years the farmer can cultivate his patch, which depends on the inherent fertility of the soil, the type of crop, and his cultural tradition. If he can cultivate it for more than one year, his land requirements will be considerably less than if he must move every year. A particularly damaging form of swidden cultivation involving a long cycle has been termed the exhaustion rays by Turbang (1961) in his excellent survey of the Lower Mekong Basin. (Ray is the local term for swidden plot.) This system is characteristic of the Meo people of the hill and mountain country of southern China and northern Viet Nam, Laos, and Thailand. The ray is cultivated intensively for seven or eight years, and the result is a leached, eroded, and exhausted plot which even grass finds it difficult to colonize.

Another variable, whose importance cannot be understated, is the length of time that the plot will be allowed to remain in fallow before being cultivated again. After being abandoned, undesirable grasses and weeds appear in the

swidden plot. With the passage of time the second-growth forest develops, consisting of light-loving trees and others that played a minor role in the original forest. Given the passage of decades, the original climax vegetation may reestablish itself, and the original soil fertility may be replenished. Unfortunately, it is most unusual for the fallow period to last for such a long time. Miracle (1964) records fallow periods in the Congo Basin ranging from one to twenty years. Credner (1935) reports periods as short as ten years. As a result of the pressure of population on the land, the shifting cultivator returns before the cycle has been completed. The productivity of the plot is now based on the degraded second-growth forest, and therefore is less than when first cleared.

All too often an abandoned swidden plot is burned before a second-growth forest can establish itself. The result is the development of the extensive open grasslands that are burned or catch fire annually, thus forestalling natural reforestation. The grasslands gradually expand at the expense of the forest by singeing the trees at the forest grassland border. These grasslands, called cogonales in the Philippines, alang-alang in Indonesia, and "derived savanna" by J. Phillips (1965), are now the dominant form of vegetation in many areas of the humid tropics, particularly where a dry season exists. It is apparent that the perennial burning cycle of swidden cultivation which involves a relatively lengthy period of forest or bush fallow, has within it a strong propensity to shorten the period and ultimately become an annual cycle when derived savanna has replaced the original or second-growth forests.

There is a variety of other perennial cycles in burning vegetation, some of which may be referred to briefly. One of these is the system wherein swidden cultivators, such as those in Indonesia, combine coffee or pepper cultivation with rice on their plots. The following table (after Pelzer, (1945)

indicates how a two-year cycle of rice is combined with a five-year cycle of coffee.

TABLE 13

SCHEME OF OPERATION OF SWIDDEN CULTIVATORS RAISING COFFEE AS
A CASH CROP IN SWIDDEN PLOTS, IN TERMS OF HARVESTS

YEAR	SWIDDEN PLOTS				
	First	Second	Third	Fourth	Fifth
1st	rice				
2nd	rice				
3rd	coffee	rice			
4th	coffee	rice			
5th	coffee	coffee	rice		
6th	coffee	coffee	rice		
7th	coffee	coffee	coffee	rice	
8th		coffee	coffee	rice	
9th		coffee	coffee	coffee	rice
10th			coffee	coffee	rice
11th			coffee	coffee	coffee
12th				coffee	coffee
13th				coffee	coffee
14th					coffee
15th					coffee

(After Pelzer, 1945)

James (1953) has described a cycle of land clearance and abandonment in the semi-deciduous forests of eastern Brazil. A large landowner, desiring to have his forested land cleared for pasture, contracts with a tenant to clear and burn an area of about four hectares. The tenant cultivates maize, rice, beans, and manioc for two or three years. Then he plants grass and moves to another plot. The landowner pastures his cattle for a few years, but gradually the grass is replaced by trees. Then the landowner moves his cattle to another pasture. By this process large areas of Brazil have been repeatedly cleared and abandoned.

c. Conclusions.--It is apparent that the levels of material technology range over a wide spectrum from the

primitive to the ultra-modern. The levels of knowledge about how to use and control fire are equally disparate. Yet it is abundantly clear, from the great variety of practices that have been described in the literature, that fire and tropical agriculture are intimately related. Fire is an agricultural tool as important to the swidden cultivator as his digging stick, as important to the European farmer in Rhodesia as his tractor.

C. Man, Land and Fire.

In order to better understand the reasons why the practices discussed in the previous section are so widely used, we should examine the geography of cultural factors that are related to the use of fire. A variety of questions might be asked. How many people use fire, and where are they located? How much land is required to support people who rely on fire? How has population growth affected the man/land ratios among fire users? What social and economic characteristics favor the use of fire? What are the possible future cultural developments that might affect the use of fire?

1. Population

a. Population Numbers.--In many tropical areas the swidden cultivators are beyond the reach of the census taker. Therefore, it is very difficult to have more than a rough estimate of the number of people who use fire. The 1957 F.A.O. estimate of 200 million should be increased to about 240 million for 1966, based on an estimated world increase of 2 per cent per year. The rate of increase of swidden cultivators has probably been highest in Latin America, where the range of population increase varies from 1.5 per cent in Jamaica to 4.3 per cent in Costa Rica. Africa has had the lowest increases, ranging from 1.1 per cent in Chad to 3.3 per cent in Southern Rhodesia. The rates for South and Southeast Asia are intermediate, ranging from 2.1 per cent in Burma to 3.7 per cent in South Viet Nam (Population Reference Bureau, 1965).

b. Population Densities.--Considerable differences exist from place to place in the tropics in population numbers and densities. According to Gourou, in 1958 the wet tropics of Asia contained one quarter of mankind on 8 per cent of the earth's usable land at an overall density of about 55 per square kilometer. The remaining wet tropical regions contained 170 million people on 28 per cent of the usable area. Tropical Africa had an estimated 120 million people, with an average density of about 8 per square kilometer, while tropical Latin America had about 60 million, with an average density of about 4.5 per square kilometer.

A brief glance at a map of world population density will make it obvious that the above statistics oversimplify the situation. In the wet tropical regions of Asia more than one half of the area is very densely populated. In India and mainland Southeast Asia particularly the areas with 10 or fewer persons per square kilometer are discontinuous islands in a densely populated sea. The opposite is true of Africa and Latin America, where most of the land is sparsely populated. There are only a few spots of relatively dense population along the coasts, in the Central American mountains, in Nigeria, and around the East African lakes.

It has been established by numerous studies (Pelzer, 1945; Gourou, 1958; et al.) that swidden cultivation in wet tropical Asia is primarily found in the hilly or mountainous areas where the cultivation of irrigated rice has not penetrated. In the alluvial valleys, where the mass of the population lives, there is no room for the extensive land use that swidden cultivation involves. The contrast may be seen by comparing Cambodia, a country that consists mostly of lowlands, with Laos, a country that is mostly hilly and mountain land. In Cambodia less than 5 per cent of the population is supported by swidden cultivation, while in Laos the figure is about 40 per cent (Turbang, 1961).

The cultivation of irrigated rice is of minor importance in most parts of Africa and Latin America. The majority of the peasant population subsists on root crops, such as manioc, yams, taro, and potatoes; on unirrigated cereal crops, such as maize, sorghum, and millets; and on miscellaneous food crops such as bananas, peanuts, and beans. It is safe to say that while in tropical Asia swidden cultivation supports a minority of the agricultural population, in tropical Africa and Latin America swidden cultivators form the majority of the agricultural population.

c. Man-Land Ratios.--In the absence of detailed census statistics, it is difficult to state exactly the population densities that are found in the areas of swidden cultivation. However, several estimates have been made of the amount of land that is required to support a community on a permanent basis. In 1940 it was estimated by Van Beukering of the Department of Economic Affairs, Netherlands Indies, that swidden cultivation could permanently support up to fifty persons per square kilometer (Pelzer, 1945). Allowing five persons per family and a one-year cultivation with nine years of fallow, the average land requirement per year would be one hectare per family. Conklin (1957b) estimated the population capacity of the Hanunóo agricultural system at 48 per square kilometer. Watters (1960) has attacked the general applicability of these estimates, citing areas of infertile land where, under the chitemene system, the durable carrying capacity is only 2.6 per square kilometer. The only certain statement possible is that swidden cultivation can persist on a stable basis only where the population density is low enough for the swidden plots to regain their fertility by a long fallow period. The length of the necessary fallow period will vary, depending on such factors as the climate, vegetation, soil parent material, and extent of damage by burning. Full recuperation after one crop may take from twelve years in Indonesia to thirty years in Southern Nigeria (Watters, 1960).

One of the most noteworthy characteristics of the agricultural population of tropical areas is their increase in recent years. Limitations on population growth, such as disease, wars, famines, and cultural restraints have gradually declined in their effectiveness. As population density has increased, the fallow period has been shortened, because less land is available for cropping and therefore a greater portion of land must be used more frequently. The tragic result of population increase often is the creation of large areas where soil is exhausted, land is severely eroded and forest vegetation has been permanently replaced by grasses and low shrubs (Turbang, 1961; Watters, 1965; Harroy, 1949; Bartlett, 1956).

2. Social and Economic Setting

Swidden cultivators and nomadic pastoralists have certain social and economic features in common. Conservatism, isolation, low level of cultural development, rudimentary land tenure relationships, and underemployment of labor are characteristic of most of these groups. Reluctance to change the patterns of living that have been developed over the centuries is not unusual among human societies. Many of their religious and social practices are intimately connected with the food-producing activities. This conservatism becomes a problem when the practices become detrimental to the survival of the group or of its neighbors, as the rise in population density and the reduction in the fallow period has proven. Perhaps basic to their conservatism and isolation are the low levels of literacy and cultural development that characterize most primitive fire users. Areas of dense population in South Asia and Southeast Asia are those where the cultures of the great river valley civilizations of India and China penetrated, bringing with them the irrigation techniques that enabled them to produce surpluses and develop a high level of culture. Except for the Mayan civilization, and

perhaps those of Zimbabwe in Southern Rhodesia and Benin in Nigeria, no great civilization based on swidden farming has developed.

The technological level of swidden cultivators may be described as that of hoe culture in Africa and digging stick culture in Asia, Oceania, and Latin America. The use of the plow is unusual, and probably unsuited to the stump-filled forest clearings. Therefore, fire is the easiest and most efficient tool for the clearing of land. Through the centuries, swidden farmers and nomadic grazers have developed adaptations to environmental limitations that make possible a durable economy, so long as man/land ratios are low. The hoe and the digging stick disturb the soil very little. By mixed cropping and cropping in sequence, the soil is protected from sun and rain and the likelihood of total crop failure is lessened. Yet the low inherent productivity of the tropical soils makes it inevitable that crop yields decline. If enough land is available, however, the question as to which may be much more costly, to clear another swidden plot, or to use fertilizer to maintain existing plots, has yet to be answered.

The character of land tenure is intimately associated with fire and swidden farming and nomadism. Usually there is no attachment of an individual to a parcel of land. In Africa, numerous tribes have a variety of land rights that are largely communal in nature, and are still imperfectly understood (N.A.S.-N.R.C., 1961). The use of the land and the production from it are more important than its ownership as real property. The pastoral peoples have their own systems, which emphasize the right to graze their animals in certain places at certain seasons, and to use certain water holes and occupy certain camp sites. In Latin America much of the land has been occupied by squatters over the centuries in spontaneous settlement. In Latin America, there is a lack of clear titles and of clearly demarcated property

boundaries. Since the farmer is planning to move in a few years, and since he has no property interest in the land, he has no inclination to improve it.

The use of fire by European controlled or influenced forestry services and commercial grazers is at a higher technological level than that by swidden cultivators and nomadic herders. Initially they attempted to prevent all fires by applying repressive measures copied from Europe. The results were unsatisfactory. Now it is recognized that it is necessary to develop suitable burning programs that are potentially capable of providing for durable watershed conservation, forest production, or high quality grazing (Guilloteau, 1957). The literature is replete with reports of experimentation on the time of burning, the immediate effects on the vegetation and soil, and the long term ecological results (Botha, 1945; Phillips, 1965; Rattray, 1964; et al.). The evidence shows the desirability that burning at this technological level continue, provided that adequate protection is provided to prevent escape of the fire.

What investment does the Latin American farmer make in the land? Watters (1965) has shown that the labor of the Venezuelan farmer and his family amounts to almost 90 per cent of his total investment, with tools and seed being the remainder. Yet only 26 to 32 per cent of the average available labor is actually utilized. The intimate interrelationship between the social and economic conditions and the persistent under-employment of labor is well expressed in the following statement:

The failure of [swidden] cultivators to utilize labour more fully seems to be a consequence of the lack of capital which prevents [them] from planting semi-permanent or permanent crops, the high premium placed on leisure time, and above all the strength of traditional custom and unquestioning adherence to archaic

methods which underlies the "culture of poverty". Increases in income rarely lead to increases in investment or labour input, but to increase leisure (Watters, 1965).

Although the statement refers to the Venezuelan swidden farmer, there is no question of its applicability to the rest of the tropical world.

3. Cultural Trends

An infinite number of variables, some known and many unknown, have contributed to the cultural mosaic of man's interaction with the diversity of tropical environments. What are the variables that contribute to perpetuating the use of fire? What are those already fostering cultural change, and hence change in the patterns of fire use?

Isolation, be it of swidden cultivators or nomadic pastoralists, promotes the persistence of cultural ways of life, inhibits contact with other cultural patterns, and promotes suspicion and resistance to change. Inasmuch as change would threaten not only economic conditions, but also deeply-ingrained cultural traditions, some of which may be most sacred, it is unlikely that the use of fire among peoples living in primitive isolation will change radically in the next half century.

Paradoxically, as contact between primitive cultures increases, there may be even greater use of fire and more damaging effects from such use. Numerous researchers have expressed deep concern over the effects of population increase, in both number and density, on the forest-fallow cycle of land use. A number of tropical countries are witnessing the expansion of swidden agriculture and the detrimental effects of fire to an even greater extent than in the past. Among such societies, where the rural population lives in a semi-feudal or tribal social and economic status, the impact of improved health and greater longevity--mixed blessings of modern technology--is either increased pressure on the land

at the same low subsistence level, or migration from the countryside to the urban centers. In many areas, both phenomena are occurring.

The use of fire as a tool in forest and pasture management is increasing. It appears justified, since at the present time no alternative to fire exists, in terms of ease of use and cost. As commercial exploitation of these resources expands, also under pressure of increasing population, fire use is bound to expand. Fortunately, controlled burning and fire control go hand in hand. Thus devastation from accidental and uncontrolled fires may well decline.

A number of trends are observable in the tropical world that may alter the pattern of fire use. First, the number of dams and reservoirs is increasing. The need for watershed protection to reduce storm runoff, prevent excessive silting, and promote rainfall infiltration has been recognized. Second, need for timber from the tropical forests is increasing, both for domestic purposes and for export. Recognition by governments of the value of forest resources should facilitate the introduction of curbs on swidden cultivation, increase the use of control burning, and accelerate the planting of valuable species. Third, the rise of nationalism in the tropical world will lead to a greater consciousness of territorial integrity, the demarcation of boundaries and the extension of transportation routes to border areas. As a result the nomadic pastoralists and swidden cultivators who have been migrating across international boundaries without hindrance may be prevented from so doing. Fourth, the development of property rights in land, the expansion of cadastral mapping, and the granting of land titles will make it possible for small farmers to improve their land, and in so doing, develop changes in attitude. Fifth, improvements in transportation facilities will make it possible to introduce cash crops, commercial grazing and dairying to areas previously self-sufficient.

In all likelihood there will never be complete abolition of fire in the tropical world. Nevertheless, attempts have been made to transform the ways of life of the inhabitants so as to make burning less necessary. Planned settlement schemes, such as the paysannats indigènes in Congo (Léopoldville), the Native Land Husbandry Act settlements in Southern Rhodesia, and the activities of the Instituto Agrario Nacional in Venezuela introduce former swidden farmers to fertilizers and new techniques on permanently cultivated land. Various other measures have been suggested, such as non-inflammable forest belts between clearings, clearing on the contour, mixed farming (Pelzer, 1945), tree crops, dairying, commercial grazing (Watters, 1965), and irrigated rice cultivation (Gourou, 1958).

D. Conclusions

Man's activities have made a tremendous impact on the natural features of the tropical world. As a result of repeated burning, vast areas of tropical forest have been altered, an unknown portion permanently. Due to man's proclivity to select the savanna/forest boundary for his swidden cultivation, the forest has retreated, and many authorities question whether much of the humid broadleaf evergreen forest is not in fact mature second growth. Increase in runoff and soil erosion in many tropical areas has been documented in detail. Furthermore, river flows are known to have become much more fluctuating than in the past, particularly for parts of Africa and Asia.

The complexity of the problem is evident when it is realized that it is not possible to separate the cultural environment from the physical environment. Basic to the use of fire by swidden cultivators and pastoral peoples, for example, are the physical characteristics of the soil and vegetation. If tropical soils were of higher natural fertility, the necessity for the farmer to shift his swidden plot would not be present. The pastoralist burns pastures

for many reasons, but they include recognition that he needs to remove old grasses prior to new growth, and that fire sustains grasses in areas that normally would support brush and woodland.

Yet these physical factors do not control man's use of the land. Equally important is the level of cultural development, in which the basic conservatism of man-land relationships all too often has retarded the acquisition of new technical skills and has magnified problems. Swidden cultivators and nomadic pastoralists long had developed a stable relationship with the land, dependent on low numbers of population per unit of land area. The impact of modern socio-economic values and technology upset the old balance between man and land. A major question, becoming increasingly more pressing, is what are the studies necessary to insure sound planning and stable future development at new economic levels of productivity between man and land, yet at the same time reduce the adverse effects of fire. More detailed understanding of the relation of cultural factors to the use of fire is needed. Selected examples of possible future studies that would contribute to the planning process are:

- 1) field studies in tropical regions to determine the spatial extent of burning and to gain more precise knowledge of changes that are taking place;
- 2) studies of the communication of information and the diffusion of change in preliterate societies, including the development of models;
- 3) studies of the psychopathology and sociology of pyromania and incendiarism;
- 4) studies on planning of fire reporting and fire control systems, with emphasis on the rational planning of facilities, personnel, methods, and objectives;
- 5) studies on the development and utilization of chemical and biological agents to fireproof susceptible areas, such as lands alongside roads, railroads, encampments, and settlements;

- 6) studies on the feasibility of remote sensing of potential combustibility by air and satellite-borne instruments:
- 7) studies to develop photo interpretation keys, automated photo interpretation, and computerized map compilation for tropical areas subject to burning.

REFERENCES CITED

- Aitken, W. Ernest (1964) Personal communication.
- Allen, C. W. (1916) Teak taungya plantations in the Henzade-Maubin division, Ind. For., 42:533-537.
- Baker, Simon (1965) Land use along a tropical climatic boundary: the Walawe Ganga Basin of Ceylon, Ph.D. dissertation, Clark University, Worcester, Massachusetts.
- Bates, M. (1948) Climate and vegetation in the Villavicencio region of eastern Colombia, Geog. Rev., 38:555-574.
- Bartlett, H. H. (1956) Fire, primitive agriculture and grazing in the tropics, In: Thomas, William Jr. (ed.), Man's role in changing the face of the earth, University of Chicago Press, Chicago, pp. 692-720.
- Botha, J. P. (1945) Veld management in the Eastern Transvaal Repr. from Farming So. Africa, Reprint No. 65, Government Printer, Pretoria, 5 pp. (repared).
- Cockbill, Gerald F. (1955) Pers. comm. in Bartlett (1955-61) II.
- Conklin, Harold C. (1957a) Hanunóo agriculture in the Philippines, Unasylva, 11, No. 4:172-173.
- Conklin, Harold C. (1957b) Hanunóo agriculture: a report on an integral system of shifting cultivation in the Philippines, FAO Forestry Development Paper, No. 12, 209 pp.
- Credner, Wilhelm (1935) Siam: das Land der Tai: eine Landeskunde auf Grund eigener Reisen und Forschungen, J. Engelhorn's Nachf., Stuttgart, 422 pp.
- Davis, Charles M. (1959) Fire as a land use tool in north-eastern Australia, Geog. Rev., 49:552-560.
- de Schlippe, Pierre (1955) Shifting cultivation in Africa: the Zande system of agriculture, Routledge and Kegan Paul, London, 304 pp.
- Division of Anthropology and Psychology, National Academy of Sciences (1961) Human environments in Middle Africa, National Research Council, Washington, D.C., 132 pp.

- Gammon, D. M. (1962) Veld fire control, Phodesia Agric. Jour., 59, No. 4:177-191.
- Gawthorn, D. J. (1962) Jungle clearing, Planters' Bulletin of the Rubber Research Institute of Malaya, 62:103-108.
- Giffard, P. L. (1965) Personal communication.
- Gillin, John (1936) The Barama River Caribs of British Guiana, Papers of the Peabody Museum of Amer. Archeol. and Ethnol., Harvard Univ., 274 pp.
- Gonzalez, Silva, J. M. (1957) Los incendios de Brazil y Venezuela, Agr. Venezol., 21, No. 193:22-23.
- Gourou, Pierre (1958) The tropical world: its social and economic conditions and its future status, 2nd ed., Longmans, Green and Co., London. New York, Toronto, 159 pp.
- Guilloteau, J. (1957) The problem of bush fires and burns in land development and soil conservation in Africa south of Sahara, Sols Africains, 4, No. 2:64-102.
- Harroy, Jean-Paul (1949) Afrique: terre qui meurt: la dégradation des sols africains sous l'influence de la colonisation, Marcel Hayez, Bruxelles, 557 pp.
- Huetling, A. (1906) De Zending en de Landbouw, Mededeelingen van Wege det Nederlandsche Zendelinggenootschap, 50:387-412.
- Huke, R. E. (1954) Economic geography of a North Burma Kachin village, Unpublished: presented at the meetings of the Far Eastern Association, New York, April 13-14, 1954, 24 pp.
- James, Preston E. (1953) Trends in Brazilian agricultural development, Geog. Rev., 43, No. 3:301-328.
- Marwick, B. A. (1940) The Swazi, Cambridge University Press, Cambridge, 320 pp.
- McArthur, A. G. (1962) Control burning in eucalypt forests, Leaflet No. 80, Forestry and Timber Bureau, Canberra.
- Miracle, Marvin P. (1964) Traditional agricultural methods in the Congo Basin, Food Research Institute, Stanford University, California, 219 pp.
- Oracion, Timoteo S. (1963) Kaingin agriculture among the Bukidnons of South-Eastern Negros, Philippines, Jour. of Trop. Geog., 17:202-212.
- Overholt, Dr. William (1963-64) Personal communication.
- Parsons, D. J. (1960a) The systems of agriculture practiced in Uganda, Uganda Department of Agriculture, Memoirs, Series 3, No. 5, Kwanda Research Station, Kampala, 27 pp. (mimeogr.).

- Parsons, D. J. (1960b) The systems of agriculture practiced in Uganda, Northern Systems Pt. I - The Lango-Acholi System; Pt. II - The West Nile System, Uganda Department of Agriculture, Memoirs, Series 3, Kwanda Research Station, Kampala, 66 pp., (mimeogr.).
- Pelzer, Karl J. (1945) Pioneer Settlement in the Asiatic Tropics: Studies in Land Utilization and Agricultural Settlement in Southeastern Asia, Chapter II, "The Shifting Cultivator," pp. 16-34, New York: American Geographical Society, 1945, 290 pp.
- Phillips, John (1965) Fire--as master and servant: its influence in the bioclimatic regions of trans-Saharan Africa, Fourth Annual Tall Timbers Fire Ecology Conference, Proc., March 18-19, 1965, Tall Timbers Research Station, Tallahassee, Florida, pp. 7-109.
- Population Reference Bureau (1964) Population Information for 129 Countries, World Population Data Sheet, Information Service, Population Reference Bureau, Washington, D.C.
- Rattray, J. M. (1964) Personal communication.
- République du Sénégal (n.d.) Nature et caractéristiques du feu de brousse au Ferlo, Ministère de l'Économie Rurale. Service des Eaux, Forêts et Chasses. Dakar.
- Richards, Audrey I. (1939) Land labour and diet in Northern Rhodesia: an economic study of the Bemba tribe, Oxford University Press, London, 423 pp.
- Sanderson, S., C. P. Menon, and S. Ganapathy (1962) Notes on the burning of jungle, Planters' Bulletin of the Rubber Research Institute of Malaya, 62:109-112.
- Scott, J. D. (1952) The management of range pastures (veld) in Africa, Sixth Inter. Grasslands Cong.. 1:477-483.
- Stewart, Omer C. (1956) "Fire as the First Great Force Employed by Man", in: Thomas, William L. Jr, Man's Role in Changing the Face of the Earth, Chicago, Univ. of Chicago Press, 1956, pp. 115-133.
- Stocker, G. C. (n.d.) "Notes on the occurrence and effects of vegetation burning in the Northern Territory", (Manuscript, in press), 18 pp.
- Tamayo, Francisco (1962) Incendio de sabanas: Procedimiento irracional y ruinoso. Reprint from: 1º Forum de Conservacion de Recursos Naturales, (repaged), pp. 3-8, Caracas.
- Trapnell, C. G. and J. N. Clothier (1937) The soils, vegetation and agricultural systems of northwestern Rhodesia, Report of the Ecological Survey, Government Printer, Lusaka, 69 pp.

- Turbang, J. (1961) Forest and grassland fires in the Lower Mekong Basin, Report of FAO to ECAFE, Committee for Co-ordination of Investigations of the Lower Mekong Basin, Twelfth session, Saigon, Vietnam, Feb. 1961, 44 pp.
- Ward, R. Gerard (1960) Village agriculture in Viti Levu, Fiji, New Zealand Geog., 16, No. 1:33-56.
- Watters, R. F. (1960) The nature of shifting cultivation: a review of recent research, Pacific Viewpoint, 1, No. 1: 59-99.
- Watters, R. F. (1965) Shifting cultivation in Venezuela, FAO Report (Forestry and Forest Division), 140 pp. (manuscript).
- West, O. (1958) Bush encroachment, veld burning and grazing management, Rhodesia Agric. Jour., 55, No. 4:407-425.
- White, J. S. L. (1945) Notes on the opening by manual labour of land in the dry zone of Ceylon, The Trop. Agriculturist, (Ceylon), 101:148-152.
- Williams-Hunt, P. D. R. (1952) An Introduction to the Malayan Aborigines, Kuala Lumpur, Government Printer, 102 pp.
- Wilson, Godfrey (1938) The land rights of individuals among the Nyakyusa, Rhodes-Livingstone Papers, No. 1, Rhodes-Livingstone Institute, Livingstone, Zambia, 52 pp.
- Suarez de Castro, F. (1953) Las quemias prescritas y sa importancia en la conservación de los suelos, Agr. Trop. (Colombia), 9:55-56.
- Murdock, George P. (1959) Africa, its peoples and their culture history, McGraw-Hill, New York, Toronto, London, 456 pp.

CHAPTER V

INCIDENCE AND DISTRIBUTION OF FIRE

A. Introduction

The range of occurrence and the extent of fire's effects on the physical and cultural environment have been examined in detail both from a topical viewpoint and for local areas. Equally as important are the range of occurrence, or incidence, of fire and its distribution throughout the tropical world. Certain limitations make them difficult to analyze, however. The incidence and distribution depend on a very large number of incompletely understood variables. Observations of burning vary according to date and place; therefore references to unpredictable natural or accidental fires are statistically of little value. Man-set fires, on the other hand, follow definite patterns adjusted to climatic seasons, combustibility of the environment, agricultural calendars, and religious beliefs and practices. Because references to cultural use of fire are numerous, and the climatic dry seasons and major vegetation formations are known, it is possible to present them cartographically. Consequently, in what is believed to be a first attempt, the relationships between burning, the climate, and the natural vegetation have been shown on maps of Africa, South America, Central America, South and Southeast Asia, and Southeast Asia and Northern Australia. Preceding the analyses of the maps is a discussion of the incidence and distribution of fires in terms of their cause, their frequency, and their relative significance.

B. Causes of Fire

1. Fires Due to Natural Causes

Over the centuries, man's use of fire has spread

CHAPTER V

INCIDENCE AND DISTRIBUTION OF FIRE

A. Introduction

The range of occurrence and the extent of fire's effects on the physical and cultural environment have been examined in detail both from a topical viewpoint and for local areas. Equally as important are the range of occurrence, or incidence, of fire and its distribution throughout the tropical world. Certain limitations make them difficult to analyze, however. The incidence and distribution depend on a very large number of incompletely understood variables. Observations of burning vary according to date and place; therefore references to unpredictable natural or accidental fires are statistically of little value. Man-set fires, on the other hand, follow definite patterns adjusted to climatic seasons, combustibility of the environment, agricultural calendars, and religious beliefs and practices. Because references to cultural use of fire are numerous, and the climatic dry seasons and major vegetation formations are known, it is possible to present them cartographically. Consequently, in what is believed to be a first attempt, the relationships between burning, the climate, and the natural vegetation have been shown on maps of Africa, South America, Central America, South and Southeast Asia, and Southeast Asia and Northern Australia. Preceding the analyses of the maps is a discussion of the incidence and distribution of fires in terms of their cause, their frequency, and their relative significance.

B. Causes of Fire

1. Fires Due to Natural Causes

Over the centuries, man's use of fire has spread

Controlled fires also may be set for control burning, that is, fire used as a tool to modify forest or range so as to enhance commercial exploitation. In the latter case measures employed in controlling the fire are advanced, often utilizing modern fire-fighting equipment.

The fires of swidden cultivators are in most cases controlled set fires. The area of felled forest to be used for a swidden site is usually surrounded by forest of low combustibility which acts as a green firebreak. Fires even those untended, dampen-down quickly at night in tropical rainy (Af) and monsoon (Am) climates. In dry forest formations, swidden plots frequently are aligned along the forest-savanna boundary. The grassland affords ease of movement, while forest soils are more fertile and easily cultivated. In such sites, and as population increases, the forest may become wooded savanna. The danger of fire escaping to the savannas becomes critical. Various other means of control by native peoples have been referred to in Chapter IV.

The humid tall forest environment and the forest-savanna mosaic are the most important places where swidden cultivation is found, although doubtless it is also practiced in the more wooded parts of the savanna environment (see Chapter III). It has been estimated that 36 million square kilometers are under swidden cultivation. Of these, perhaps 3 to 6 million are burned each year (see Chapter IV).

Burning with modern protective measures does not completely coincide areally with the use of control burning employed to prevent excessive accumulation of fuels. Gammon (1962) has referred to the burning of veld with inadequate precautions against the escape of fire, and to the neglect of precautionary measures such as fireguards. Nevertheless the use of controlled burning has become a common feature of pasture and forest management in Africa, India, Thailand, Burma, and Australia. The areal significance of

modern controlled burning is greatest in Africa and Australia but it still is far less than swidden cultivation.

b. Uncontrolled Set Fires.--Uncontrolled set fires are the largest single group of causes of fires in the tropical forests and grasslands. Included as uncontrolled are fires accidentally out of control, fires set by aboriginals and left untended and fires set for the sheer pleasure of seeing flames sweep across the countryside. Additional causes of uncontrolled fires are hunters and honey gatherers, fires set by pastoral peoples to improve forage or to remove pests and predators, pyromania, and fires used to harass enemy peoples. It should be noted that numerous researchers believe that more recognition should be given to pyromania as a cause (Richards, 1964; Phillips, 1965; Boughey, 1963). Accidental fires, such as from steam locomotives, tractor exhausts, smoldering matches and cigarette ends, are widespread and their geographic distribution coincides with lines of communication, many of which are passable only during the dry season and therefore bear heavy traffic. The change in incidence of fire in remote area opened recently by a road has received comment by numerous authors.

The world-wide significance of uncontrolled set fires and accidental fires is difficult to assess. In the few places where adequate records are available, they refer primarily to forest reserves and plantations, rather than to wild lands or grasslands. It may be helpful to attempt a qualitative assessment of their importance on the basis of the literature. In terms of the area burned, pastoral activity is the leading cause, followed by hunting and gathering, and pest and disease control. These types of fires are found mostly among the pastoral peoples and swidden cultivators of the forest-savanna mosaic and savanna environments. Escape of fire from controlled burning is a frequent occurrence in areas where this technique is employed, such as in the pine, acacia, and eucalypt plantations of

southern and eastern Africa and Australia. It is also common in swidden cultivation. Tribal warfare and pyromania may have a great impact locally, but they appear to be of less importance in terms of world distribution.

C. The Geographic Distribution of Burning

The areal distribution of burning is shown on the maps of Sub-Saharan Africa, Tropical Latin America, South and Southcast Asia, and Australia that accompany this chapter. The incidence of burning is related to major types of vegetation and the climatic dry season. The vegetation associations are based largely on physiognomy; they also take into account physiography, climate, and location. Circular symbols show the occurrence of a climatic dry season determined by the empirical method employed by Bagnouls and Gaussen (see Chapter III). A circular diagram divided into twelve parts represents the year. Analogous to the clock, each month represents one hour (Fig. 17). The dry season is shown as a stippled sector. The period of burning is shown by a wedge-shaped sector symbol, whose radius is slightly larger than the circle's. A dashed circle indicates that burning is not confined to one season, but takes place whenever a few days of dry weather permit. In all cases the presence of the burning symbol is based on specific references in the literature to the time of burning. For circles

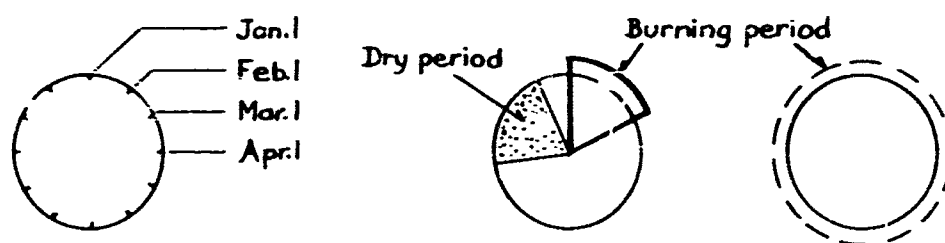


Fig. 17. Climatic and Burning Symbols used on Maps.

without the burning symbol burning may be possible and customary, but precise information was not found regarding its time of occurrence. Thus the various vegetative patterns and symbols presented on maps indicate the geographic distribution of burning, and permit comparisons to be made that are not otherwise possible.

The major contribution of the maps lies in their depiction of the interrelations of the vegetation, climatic dry season, and cultural habit of burning. But while the vegetation is shown by extensive areal patterns, the climatic dry season (an areal phenomenon) and burning season (a point phenomenon) are shown by point symbols. Undue emphasis should not be given to the vegetation patterns, since no such bias is intended. Obviously all three phenomena are highly important.

For the map of Africa, the classification and distribution of vegetation types is based on Aubréville, et al. (1958), with additional guidance from Phillips, (1965) and Rattray, (1960). The categories used on the other maps refer to climax vegetation in most cases. Since data comparable to that on Africa are not available, the vegetation categories were derived from the resources of the maps in Bartholomew's Advanced Atlas (1950), modified by information from maps and certain additional sources (Waibel, 1949; James, 1950; and the Map Division, Library of Congress).

The validity of the Bagnouls and Gaussen system has been evaluated (see Chapter III). Rainfall is subject to extreme variability from year to year in most areas, in date of seasonal onset, total amount, and date of termination. The burning symbol implies a cultural predilection for burning, not always with reference to the combustibility of the vegetation. Its accuracy depends on the reports of anthropologists, geographers, travelers, government officers, and others.

The reliability of the maps is contingent on the validity of sources. Every effort was made to assure that the utilization of the sources was accurate. However, it should be understood that the maps are "first approximations," whose chief contribution is to depict the overall pattern of burning. It is believed that they are a first attempt to combine on a single display the three factors that most influence the patterns of burning in the tropical world. Their value lies in the possibility that the patterns shown on them will stimulate further detailed research to describe and explain the distribution and changes in the use of fire.

1. Sub-Saharan Africa and Madagascar

The geographic distribution of burning in Africa and Madagascar is depicted on three map sheets (Maps 5, 6, and 7). Ten vegetation formations provide an indication of potential fuels, while the symbols indicate the correlation, if any, between climate and probable period of burning. The maps will be analyzed in terms of selected examples within broad groupings of natural vegetation and climate.

The maps indicate that burning is closely related to cultural traditions which are derived from centuries of interaction with the physical environment. The cultural factor is pronounced in those areas where the climate has no ecologically dry period (a month whose average precipitation is less than 25 mm.) and tall forest comprises the major vegetation association. Thus, in the Congo Basin, westward along the Gulf of Guinea, and eastward into East Africa, the burning symbols reveal a surprising diversity considering the overall uniformity of the environment. For example, at Lodja, Congo (Léopoldville) (Sta. 78), burning may occur at any time, while nearby it occurs in July and August at Port Francqui (Sta. 77), September and October at Kindu (Sta. 80), or December and January at Stanleyville (Sta. 75). In Cameroon burning takes place at Ambam (Sta. 38) in both the wet and dry seasons. In the highlands of

East Africa Usumbura, Burundi (Sta. 84) and Bukavu (Sta. 81) across the border in Congo (Léopoldville) experience similar dry seasons, but burning takes place at opposite times of the year. The explanation of these anomalies is that burning in the forested environment depends largely on human action in felling or killing the trees, rather than on the dry season. The cultural basis of this diversity is attested by Maps 3 and 4 (Chapter IV) which substantiates assertions of numerous writers that there is no significant climatic factor controlling time of burning in tropical rainy (Af) climatic areas supporting rainforest and humid montane forest.

Peripheral to the Congo Basin and the Guinea Coast, transition occurs in both climate and natural vegetation. Although no distinct dry season may occur, one to three months may be ecologically dry. Shifting cultivation has degraded the tall, semideciduous forest so that forest and grass or brush covered abandoned clearings coexist as a mosaic. The period of burning in the forest-savanna mosaic reflects to a greater degree the influence of a drier season. In this transitional zone south of the Congo Basin, burning takes place at the end of the dry season and possibly extending into the period of first rains. Topographic relief appears to exercise little direct influence, as indicated by Kabalo, Congo (Léopoldville) (Sta. 82) and Brazzaville, Congo (Brazzaville) (Sta. 95). In Nigeria, however, there are distinct differences in the periods of burning at Enugu (Sta. 32) and Ibadan (Sta. 31). Both stations are located in the forest-savanna mosaic. They have almost identical dry periods both as to time of occurrence and duration. A possible explanation is that adjacent grasslands are fired during the dry season whereas shifting cultivators clear and burn either in December and January, or in June or July. Although specific references to burning could not be plotted for other stations in the West

African forest-savanna mosaic, it is known that burning early in the dry season is the official government forest policy.

Similarly, forest-savanna mosaic is found along the southeast coast of Africa and western coast of Madagascar. Indirect evidence suggests that the period of burning in these areas is during the last shower weather of onset of the dry period and extending well into the dry season. Because no specific references to the burning period were available, the sector symbol is not shown for stations in these areas.

Savannas of various types are very widespread in Africa, and therefore the symbols depict a number of variations of wet and dry tropical climate. At most stations, however, the dry season is well-defined, with ecologically dry months varying from more than three to more than six. The protracted period of desiccation is highly conducive to fire and it is so common that specific references to burning are surprisingly few. Generally, references to fire in the literature are so vague, that one may imagine that a whole area goes up in flames each year. In spite of the widespread occurrence of fire, however, the period of burning at most stations for which information is available rarely coincides entirely with the dry period. It is for this reason, that generalized references suggesting fire during the entire season were not evaluated in the preparation of the maps.

There is little doubt that burning coincides with the dry season in a general way, but it also reflects both primitive cultural practices and the burning policies of technologically advanced people. For example, at Lomé, Togo (Sta. 25) and Tibati, Cameroon (Sta. 153) burning occurs early in the dry season, and may well reflect policies designed to use fire to reduce fuel accumulation in wooded savanna to promote regeneration of woodlands. Also, primitive

cultivators frequently burn early preparatory to gathering and hunting expeditions in adjacent forests. Mid-dry season burning occurs at Bouca, Central African Republic, (Sta. 41) while at Wau, Sudan (Sta. 53) burning occurs in any season. Even though both stations experience a similar dry season, with a slightly longer period at Wau, the difference in burning may be related to pastoral activities at the latter station rather than significant changes in the vegetation and climate. In the eastern highlands of Africa, north and east of Lake Victoria, it is clear that burning occurs in relation to agricultural calendars of shifting and sedentary farmers rather than solely to climate, as evidenced by the periods shown at Juba, Sudan (Sta. 53), Kitgum, Uganda (Sta. 61) and Nakuru, Kenya (Sta. 65). Part of the reason for burning extending one or more months into what appears to be a rainy season is that there occurs a period of brief showers prior to onset of heavy rains.

In wooded savannas south of the Congo Basin the preferred burning period is at the end of the dry season or during first showers of the rainy season. Here too the period of burning reflects policies based on ecological studies of the effects of fires on grasslands and wooded areas. For a number of reasons, burning late in the dry season is both of frequent occurrence and the recommended practice (see stations 111, 113, 110, 107, 109 and 106).

As mentioned earlier, specific references to burning in the open grasslands both north and south of the equator are very few. Part of the reason is that rainfall variability is greater in the drier climates associated with the geographic distribution of these grasslands, than in the wooded savanna areas. Pastoral activities, both nomadic and commercial, occur as well as commercial irrigation and dry farm agriculture along with primitive cropping. Because of the diversity of land uses, it is probable that some burning is taking place within any area during most of the dry season. Examples would be burning of commercial cotton

stubble following harvest, later burning of pasture grasses by nomadic herdsmen who will return to a new flush of grass after the first rains, burning late in the dry season by commercial graziers for the same reason, and clearing of wooded areas for swidden agriculture by primitive cultivators. To the uninitiated it may well seem that burning occurs everywhere during the dry season. In a sense this is true; however, it should be made clear that burning is not necessarily chaotic or random. One should also note that certain areas are sparsely populated, and hence burning is sporadic.

2. Latin America

The distribution of major types of vegetation and climate in Latin America is a complex pattern in which the factor of relief is very significant (Maps 7, 8 and 9). Major relief features, such as the Guiana and Brazilian Highlands, Andean Cordillera and the Central American mountains and Antillian Arch, all lie more or less transverse to prevailing seasonal winds. Consequently, orographic uplift and lee-slope rainshadow effects give rise to sharp differences in annual rainfall and seasonal distribution in a distance of a few kilometers in many areas. Vegetation types and their geographic distribution not only reflect differences in climate, but also are ecologically adjusted to new and old landscapes with young and senile soils. Centuries of burning, first by Amerinds, and later by European settlers, have completely altered the vegetation in many areas.

In Central America and the Islands burning, if and when it occurs, coincides with the drier or dry season occurring during the first months of the calendar year. Notable differences are evident for the stations shown, where the effects of topographic relief and orientation to prevailing winds are important factors. Although burning is widespread throughout Central America, it is practiced for a

variety of reasons. Along the Pacific coast of the isthmian link between Mexico and South America, a pronounced dry season occurs; burning, particularly in pastoral areas, takes place at the end of the dry season. Although no specific data was available during the preparation of the map, it is known that shifting cultivators and sedentary farmers burn the subtropical montane forests. At San Andres Tuxtla, Mexico (Sta. 3) burning of the forest occurs at the end of a brief dry season extending from March to May. Merida, Mexico (Sta. 5) experiences a semi-arid climate, and the burning period is from March to May. At Belize, British Honduras (Sta. 9) burning takes place, largely by Maya Indians, as soon as the rains lessen, since the drier period is brief and frequently interspersed with showers. That burning occurs even in perhumid climates is evident in Puerto Cabezas (Sta. 12) and Bluefields (Sta. 13), Nicaragua, whose annual precipitation totals exceed 3,000 mm. and 4,000 mm. respectively. Although data is not available for many stations, burning in the central highlands of Central America and in remote parts of Hispaniola is widespread.

In South America, burning that is done by Amerinds is insignificant compared to the areas burned by the descendants of the European settlers. So ubiquitous is fire, that very few specific references describe in detail the times or purpose for burning. In many cases, references in which burning is mentioned are technical pamphlets or propaganda aimed at farmers. In either case, the audience of the author is presumed to be fully informed on local and regional agricultural practices in which fire is used. This is most unfortunate, because only 11 stations, located in diverse types of environment, could be plotted with a burning sector symbol. Conclusions concerning burning, therefore, must be drawn with care. At St. Ignatius (Sta. 39) and Tumeremo (Sta. 34), the period of burning refers to shifting cultivation by Caribs in the Rupununi district

of Guyana. At San Fernando de Apure, Venezuela (Sta. 27) the reference is to the practices of the Yaruro Indians. Rather interesting is the fact that burning by the Indians, both in Venezuela and Guyana, coincides with the general practice of burning of the savannas at the end of the dry season throughout much of tropical South America. The uniformity and predictability of this practice is due not only to the prevalence of extensive grazing and primitive slash-and-burn cultivation. Control burning in forests and advanced pasture management techniques, which might suggest the use of fire at other seasons, have made little headway.

3. South Asia, Southeast Asia, and Northern Australia

Nine major vegetation types are found on the land of Asia and Northern Australia (Maps 10 and 11). Their geographical distribution is exceedingly complex, due to the influence of the monsoon circulation, the insular and peninsular shape of the land, the irregular topography, and the area's great latitudinal extent. It is important to bear in mind that, particularly in Southeast and South Asia, centuries of occupation under systems of intensive subsistence agriculture, swidden farming, plantation agriculture, and logging have largely transformed the original vegetation into agricultural land, second growth forest, and savanna. The climax vegetation persists only where the impress of man has been slight. Therefore caution should be used in assessing the interrelation of vegetation, climatic dry season, and burning. The cultural practices of the human society inhabiting an area may be to burn at certain seasons, but due to the fact that the forest has been degraded, and the abandoned clearings are overgrown with Imperata cylindrica, uncontrolled "accidental" fires can sweep through them practically anytime.

The pattern of burning in the forested environment, which includes the montane forest and grassland, the tropical rainforest, and the moist semideciduous forest, epitomizes

the complexity resulting from varied physical conditions and diverse cultural practices. Numerous stations in the equatorial zone, extending from Colombo, Ceylon (Sta. 1) eastward to Madang, New Guinea (Sta. 55), have no climatic dry season, although brief periods of lower rainfall usually occur. The season of burning is extremely varied in this zone, however. Burning occurs all year in Madang, New Guinea and Buntok, Borneo, Indonesia (Sta. 40). Dual burning seasons are found in Jesselton, Sabah (Sta. 32) and in Kuala Panu, Malaya (Sta. 29). This indicates that advantage is taken of "breaks" in the rains that occur during the transitional period when the monsoon wind circulation is changing direction. Most of the remaining stations that have no dry season burn for two or three months during the period from May to October; e.g. the following locations in Indonesia: Manado (Sta. 44), Pontianak (Sta. 39), Lahat (Sta. 35), and Padang (Sta. 34). It should be borne in mind that orographic rainfall and rain shadows give rise to pronounced contrasts within the space of a few kilometers.

The islands of Java, Sulawesi, and Timor have dry seasons of up to seven months duration, although the vegetation remains forest. Burning occurs during the dry season, as in the Sulawesi locations of Kendari (Sta. 43) and Makassar (Sta. 42). In northern Australia the climatic dry seasons are considerably longer, yet tropical rainforest persists along the coast. The burning season is longer than the dry season at Crooktown (Sta. 61) and Darwin (Sta. 57). This indicates that burning before the last rains have ceased may be used to prevent accumulation of fuel in forests, while burning late in the dry season may be used as part of a program of pasture management.

The forested environment in the Philippines, mainland Southeast Asia, and South Asia has a climatic dry season that lasts up to eight months, and is associated with

the "winter monsoon" period. For much of this area the use of fire is associated with swidden cultivation and occasional hunting and pyromania in the uplands and hills. Most of the level land and river valleys are in permanent paddy rice cultivation, where burning is rare, except for burning of rice stubble where it is not fed to animals. In India representative locations in the Central Indian Hills are at Bhopal (Sta. 8), Raipur (Sta. 9), Ranchi (Sta. 11), and near Calcutta (Sta. 12). Comilla, East Pakistan (Sta. 13), Toungoo, Burma (Sta. 16), and Luang Prabang, Laos (Sta. 21) are similar. The burning takes place near the end of the dry season, after the forest has been felled and allowed to dry. A noteworthy exception is near Poona, India (Sta. 7), where the characteristic early dry season burning pattern is used for control burning in teak forests.

The forest-savanna mosaic includes the dry semi-deciduous forest in North India and eastern Java, and the semi-arid woodland and thorn shrub in South India, the Dry Zone of Burma, and in Thailand and Indochina. These areas have long been under intensive cultivation. Little fuel is available to burn after the population has cut brush for firewood and the animals have grazed and browsed. Where burning does take place it is in the dry season, as shown by Bangalore, India (Sta. 5), Mandalay, Burma (Sta. 15), and Surin, Thailand (Sta. 19).

The savanna environment includes open wooded savanna in northern Australia and savanna grassland in northern Australia and New Guinea. The savanna grassland in New Guinea is believed to be due to wet soil conditions in the lowlands, and to swidden cultivation in the interior highlands. Burning has been mentioned in the literature for both locations. In northern Australia burning is used by cattle and sheep raisers in order to secure a flush of green grass. The symbols on the map show very lengthy burning seasons, lasting up to seven months, as in Poome,

Australia (Sta. 56). The burning pattern of this area has been illustrated and discussed in Chapter III.

4. Oceania

The island chains of Melanesia, Polynesia, and Micronesia are, with the exception of New Guinea, too small to show vegetation at the map scale selected. Numerous references in the literature describe swidden cultivation and cattle grazing on the Pacific Islands. Many islands have turned from subsistence agriculture to commercial coconut and sugar production, but traditional forms of agriculture persist. Much of the original forest vegetation has been converted by annual burning to grass and bamboo, that regularly catches fire.

D. Distribution of Trends in Burning

The geographic patterns of burning in relation to climate and vegetation have been described and interpreted in this chapter. It must be remembered, however, that in addition to the limitations on the analysis that were referred to earlier, the maps are static. They cannot convey, except in a very limited way, the nature, direction and pace of the changes that are taking place in the incidence and distribution of fire.

What are the trends in the use of fire in the tropical world? What are the differences from place to place in these trends? A partial answer to the first question was presented in Chapter IV. On the basis of a literature survey, the answer to the second question can only be suggested. Field research is required to elicit more precise information.

Man's use of fire in the tropical world is no longer in the stage of "ecological climax", wherein a stable, harmonious relationship to the environment exists. The impact of the West has "set in train a process that has led to rapid changes in the environment, and destroyed the old balance between man and nature" (Watters, 1960, p. 95). Thus the

specific conformation of the interrelations of man, land, and fire in any particular area can be seen as stages along a continuum of change. At one end are the areas just emerging from "ecological climax", with relatively little population increase, relatively long periods of forest fallow, and relatively little soil erosion and forest or pasture degradation. The highlands of New Guinea and the interior rainforests of the Amazon Basin are representative of this stage. Near the middle of the continuum are areas in "ecological disequilibrium", in which population growth, changes in value systems, soil erosion, and forest and pasture degradation have created a situation in which shortages of food in the rural areas have led to widespread undernourishment, accelerated deterioration of the land, and migration of rural people to cities in search of food and jobs. Many areas of tropical Africa and Latin America are representative of this stage. At the other end of the continuum, in the stage of "ecological rehabilitation", are areas in which the application of scientific knowledge and techniques has resulted in the use of fire as an instrument of forest and grassland management. Representative of this stage in the continuum are these areas in East Africa, South Africa and Australia where control burning is used, with adequate safeguards against escape of fire and a tested year-by-year plan of fire use.

With this concept of an ecological continuum in mind, it is possible, with the aid of detailed information gained from field work, to establish the position of any area in terms of the amount of progress it has made since "ecological climax". A degree of caution must be used, since a) there is spatial intermixture or interdigitation of areas of differing positions; b) individual areas will occupy either a broad or a narrow segment of the continuum, depending on the scale or level of generalization. It should also be noted that most areas of "ecological rehabilitation" are

found where Europeans have settled lands that never passed through "ecological disequilibrium". Indeed, only one case is known where primitive use of fire has been partly modified by the introduction of modern technology. This is the "teak taungya" system first developed in Burma, and now used in India and elsewhere in Southeast Asia (Blanford 1925).

It is not possible to estimate the mean per cent of area burned annually with any reasonable accuracy. The areas that are subject to burning are not necessarily burned, since the cultural factors conducive to burning are so variable. Although these factors are discussed more fully in Chapter IV, it is appropriate to mention them once more.

In areas of swidden cultivation the population density varies from 2 to 50 per square kilometer; the length of the forest fallow period may be as short as 5.5 years or as long as over 20 years; the swidden plot may be utilized from one to three years before abandonment; and the area felled may be many times larger than the area burned. In areas of the Forest-Savanna Mosaic the savanna areas are prone to annual burning, while the forest areas are used for swidden cultivation and are only partially cleared and burned. In areas where pastoral nomadism is practiced burning is more predictable than elsewhere, since there the vegetation is naturally combustible during the dry season, and the herders desire a flush of green grass for their cattle. The area burned may be as much as half of the total. In areas that are under advanced forest and pasture management practices using fire, a rotational system is normally used, in which blocks of forest or pasture are burned at suitable intervals of time.

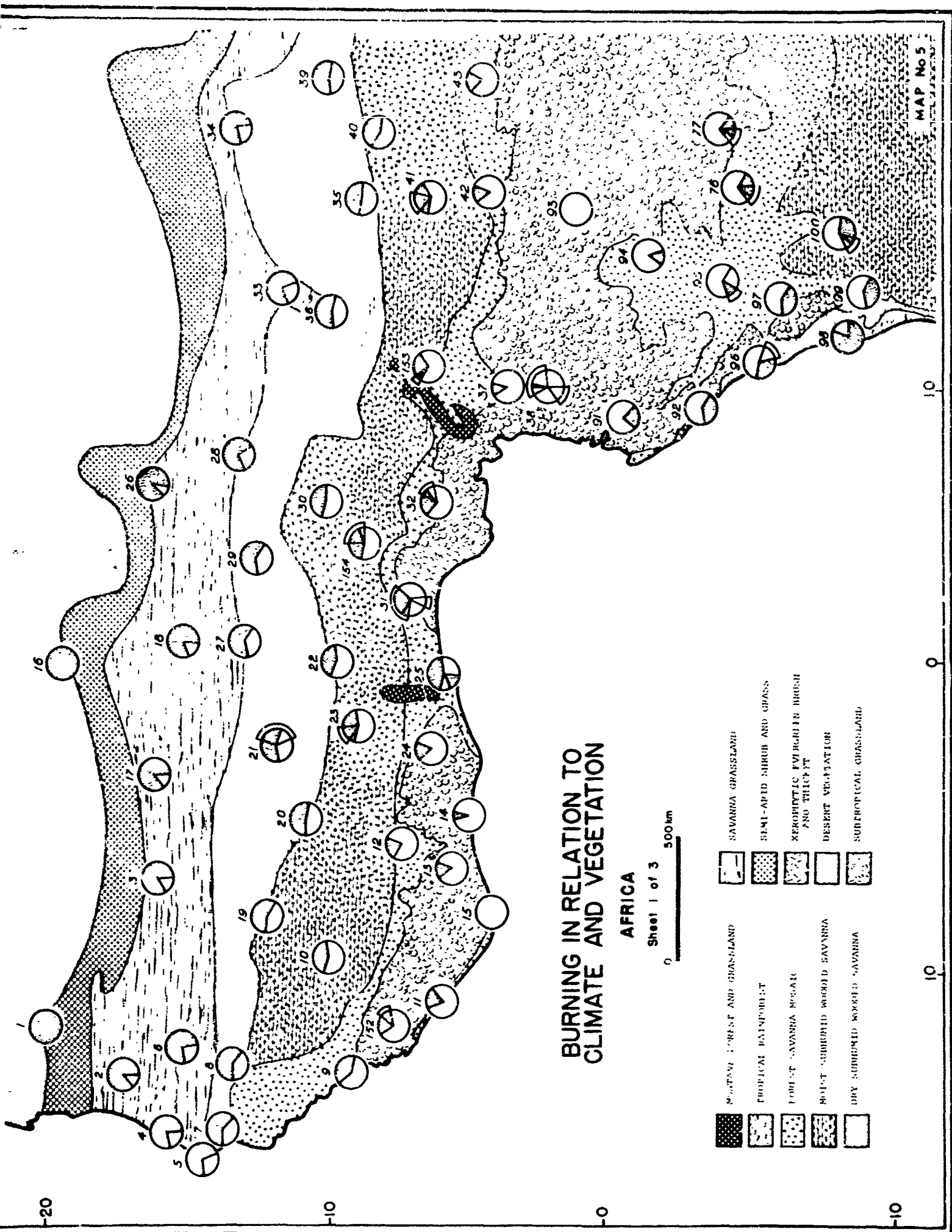
For the foregoing reasons it is evident that an estimate of the percent of area burned would be mere conjecture. The actual per cent depends on the particular combination of physical and cultural circumstances in effect in a particular area at a particular time.

INDEX TO CLIMATIC STATIONS

Map of Africa, Sheet 1

Station Number

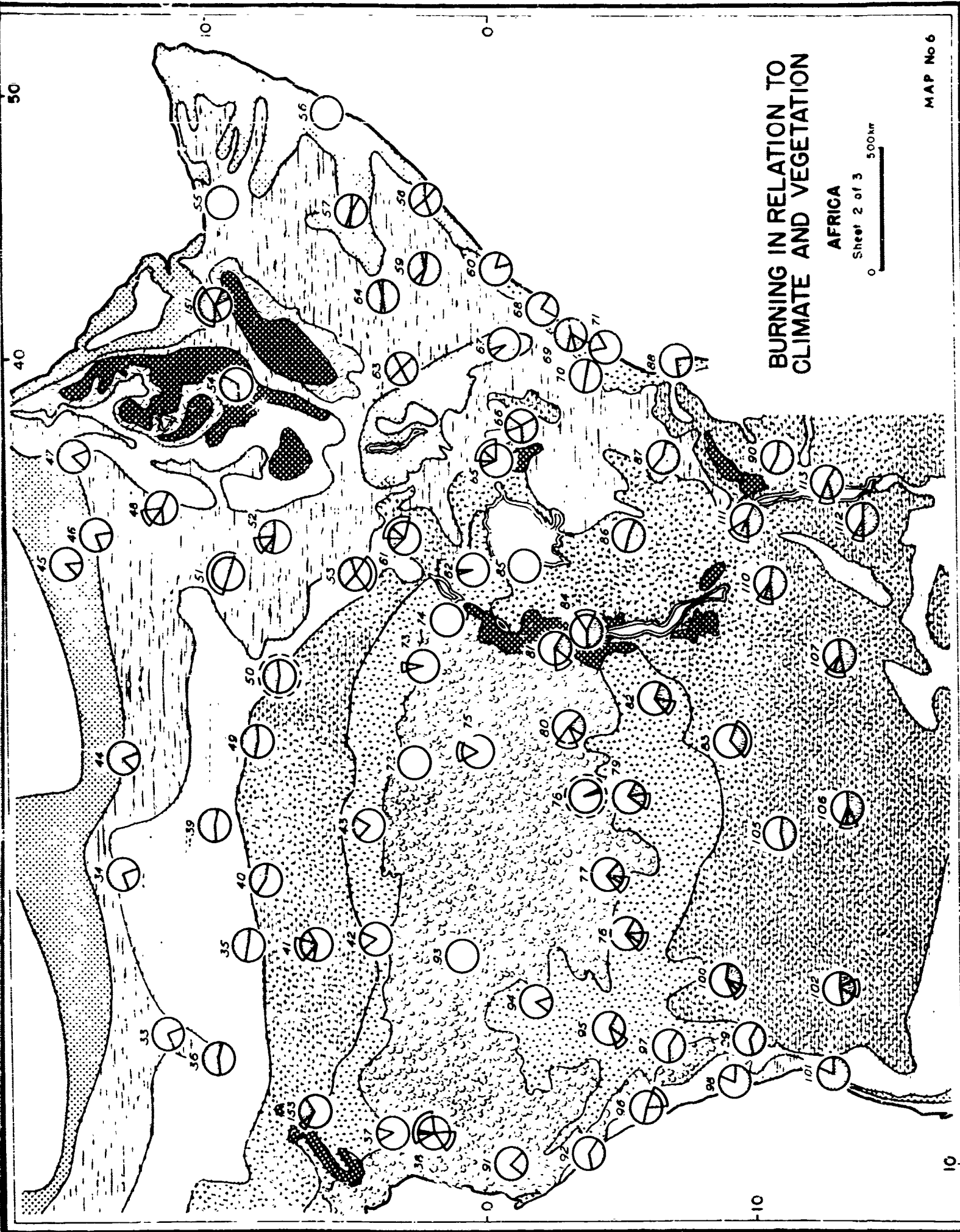
1	Atar, Mauritania	29	Sokoto, Nigeria
2	Boutilimit, "	30	Kaduna, "
3	Nema, "	31	Ibadan, "
4	St. Louis, Senegal	32	Enugu, "
5	Dakar, "	33	Fort Lamy, Chad
6	Matam, "	34	Abecher, "
7	Kaolack, "	35	Fort Archambault, Chad
8	Tambakounda, "	36	Maroua, Cameroon
9	Conakry, Guinea	37	Yaounde, "
10	Kankan, "	38	Ambam, "
11	Monrovia, Liberia	39	Birao, Central Afr. Rep.
12	Bouake, Ivory Coast	40	Ndele, "
13	Gagnoa, "	41	Bouca, "
14	Abidjan, "	42	Bangui, "
15	Tabou, "	43	Bangassou, "
16	Tesalit, Mali	76	Kikwit, Congo (Léo.)
17	Tombouctou, Mali	77	Port Francqui, Congo (Léo.)
18	Menaka, "	91	Lambarene, Gabon
19	Bamako, "	92	Mayoumba, "
20	Bobo Dioulasso, Upper Volta	93	Impfondo, Congo (Brazz.)
21	Ougadougou, "	94	Gambona, "
22	Natitingou, Dahomey	95	Brazzaville, "
23	Tamale, Ghana	96	Cabinda, Angola & Cabinda
24	Kumasi, "	97	Sao Salvador, "
25	Lomé, Togo	98	Luanda, "
26	Agades, Niger	99	Casinha, "
27	Niamey, "	100	Sunginge, "
28	Zinder, "	152	Bo, Sierra Leone
		153	Tibati, Cameroon
		154	Bida, Nigeria



INDEX TO CLIMATIC STATIONS

Map of Africa, Sheet 2

<u>Station Number</u>	<u>Name</u>	<u>Station Number</u>	<u>Name</u>
33	Fort Lamy, Chad	72	Buta, Congo (Léopoldville)
34	Abecher, "	73	Paulis, "
35	Ft. Archambault, Chad	74	Irumu, "
36	Marua, Cameroon	75	Stanleyville, "
37	Yaonde, "	76	Kikwit, "
38	Ambam	77	Port Francqui, "
39	Birao, Cent. Afr. Rep.	78	Lodja, "
40	Ndele, "	79	Lusambo, "
41	Bouca, "	80	Kindu, "
42	Bangui, "	81	Bukavu, "
43	Bangassou, "	83	Karina, "
44	El Fasher, Sudan	84	Usunabura, Burundi
45	Khartoum, "	85	Bukoba, Tanzania
46	Wad Medani, "	86	Tabora, "
47	Kassala, "	87	Dodoma, "
48	Roseires, "	88	Dar es Salaam, Tanzania
49	Raga, "	90	Songea, "
50	Wau, "	91	Lambarene, Gabon
51	Malakal, "	92	Mayoumba, "
52	Akobo, "	93	Impfondo, Congo (Brazzaville)
53	Juba, "	94	Gambona, "
54	Addis Ababa, Ethiopia	95	Brazzaville, "
55	Burao, Somalia	96	Cabinda, Angola & Cabinda
56	Obbia, "	97	Sao Salvador, "
57	Belet-Uen, Somalia	98	Luanda, "
58	Afgoi, "	99	Casinha, "
59	Bardera, "	100	Sunginge, "
60	Chisimaio, "	101	Benguela, "
61	Kitgum, Uganda	102	Chitembo, "
62	Mubende, "	105	Villa Teixeira, "
63	Moyale, Kenya	106	Balovale, Zambia
64	Mandera, "	107	Ndola, "
65	Nakuru, "	110	Kasama, "
66	Nairobi, "	111	Karonga, Malawi
67	Garissa, "	112	Lilongwe, "
68	Lamu, "	113	Maniamba, Mozambique
69	Malindi, "	151	Dire Dava, Ethiopia
70	Voi, "		
71	Mombasa, "		



BURNING IN RELATION TO
CLIMATE AND VEGETATION

AFRICA

Sheet 2 of 3
0 500 km

MAP No 6

INDEX TO CLIMATIC STATIONS

Map of Africa, Sheet 3

Station Number			
68	Lamu, Kenya	114	Nampula, Mozambique
69	Malindi, Kenya	115	Chemba, "
70	Voi, "	116	Mabote, "
71	Mombasa, "	117	Pafuri, "
76	Kikwit, Congo (Léo.)	118	Salisbury, Rhodesia
77	Port Francqui, "	119	Bulawayo, "
78	Lodja, "	120	Tsumeb, Southwest Africa
79	Lusambo, "	121	Windhoek, "
80	Kindu, "	122	Gobabis, "
81	Bukavu, "	123	Keetsmanshoop, "
82	Kabalo, "	124	Maun, Bechuanaland
83	Kamina, "	125	Serowe, "
84	Usumbura, Burundi	126	Kanye, "
86	Tabora, Tanzania	127	Pietersburg, South Africa
87	Dodoma, "	128	Carolina, "
88	Dar es Salaam, Tanzania	129	Kuruman, "
89	Lindi, "	130	Upington, "
90	Songea, "	131	Kimberley, "
92	Mayoumba, Gabon	132	Beaufort West, "
95	Brazzaville, Congo (Brazz.)	133	Graff Reinet, "
96	Cabinda, Angola & Cabinda	134	Pietermaritzburg, "
97	Sao Salvador, "	135	Masaru, Basutoland
98	Luanda, "	136	Stegi, Swaziland
99	Casinha, "	137	Dzaoudzi, Malagasy
100	Sunginge, "	138	Diego Suarez, Malagasy
101	Benguela, "	139	Antalaha, "
102	Chitembo, "	140	Mandritsara, "
103	Sa'da Bandeira, "	141	Marovoay, "
104	Mupa, "	142	Maintirano, "
105	Villa Teixeira, "	143	Tamtave, "
106	Balovale, Zambia	144	Tananarive, "
107	Ndola, "	145	Morondava, "
108	Livingstone, Zambia	146	Beroroha, "
109	Lusaka, "	147	Tulear, "
110	Kasama, "	148	Farafagana, Malagasy
111	Karonga, Malawi	149	Tsihombe, "
112	Lilongwe, "	150	Fort Dauphin, "
113	Maniamba, Mozambique		

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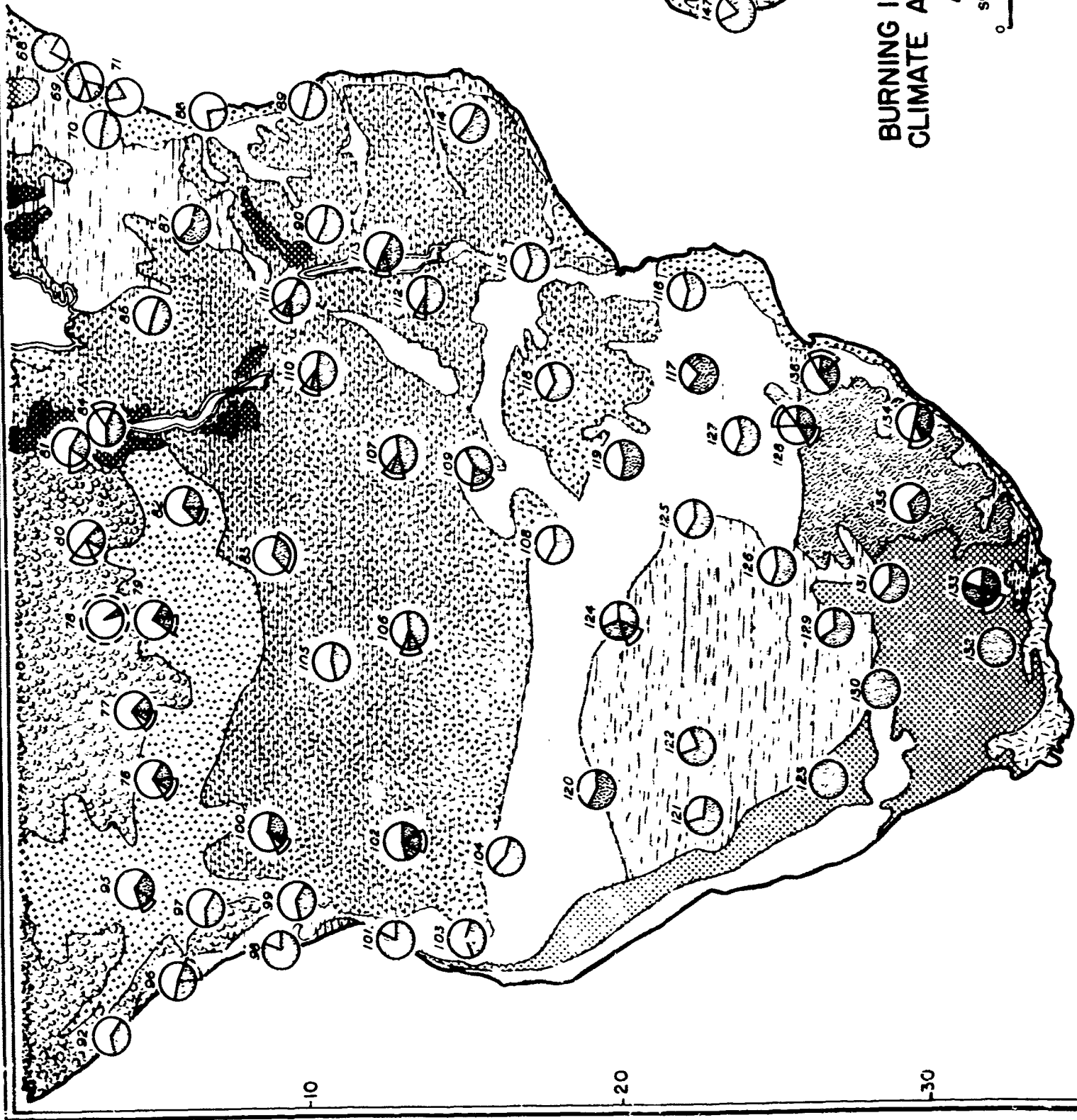
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MAP No 7

BURNING IN RELATION TO
CLIMATE AND VEGETATION
AFRICA

Sheet 3 of 3
0 500 km



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-10

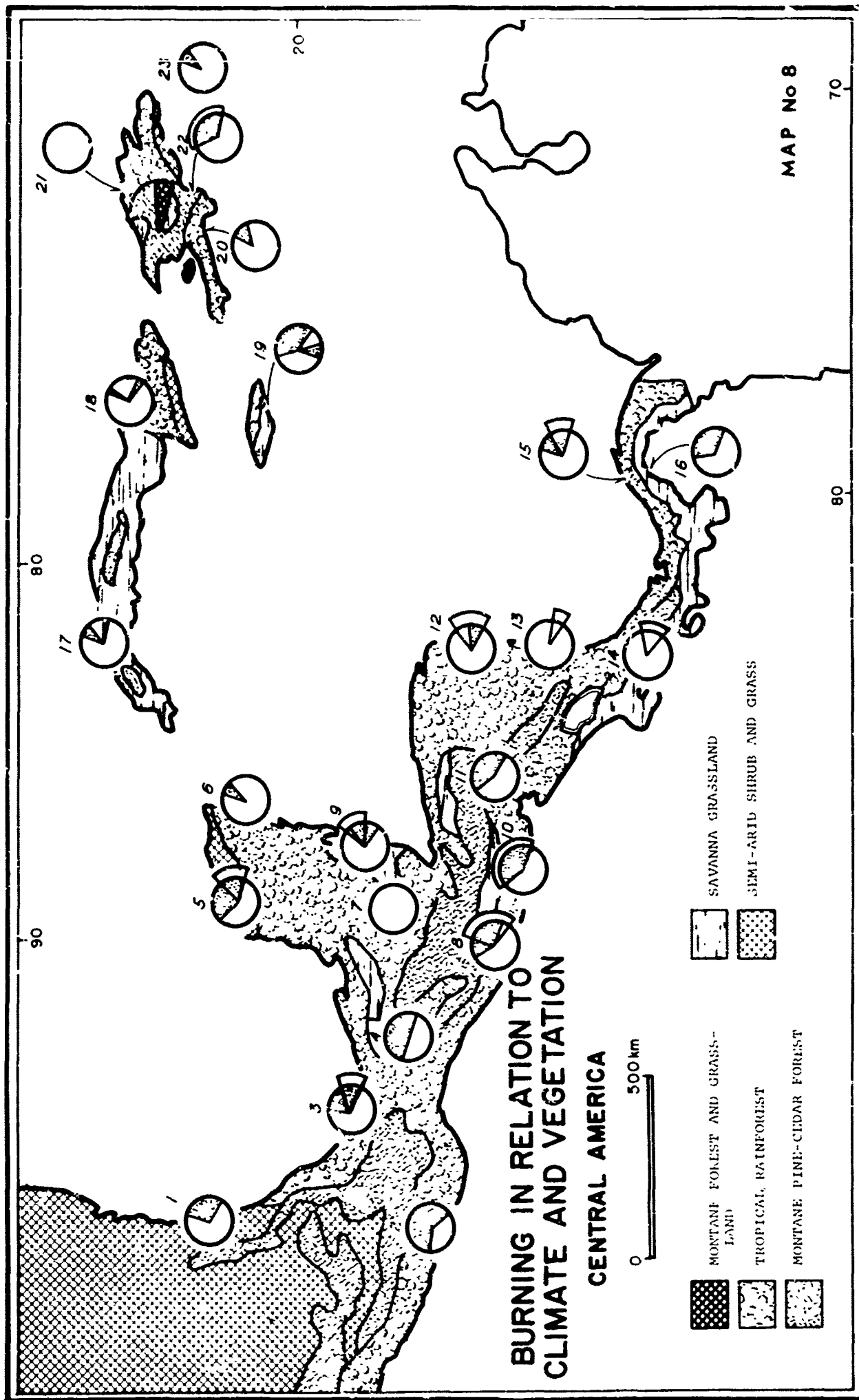
-20

-30

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Map of Central America

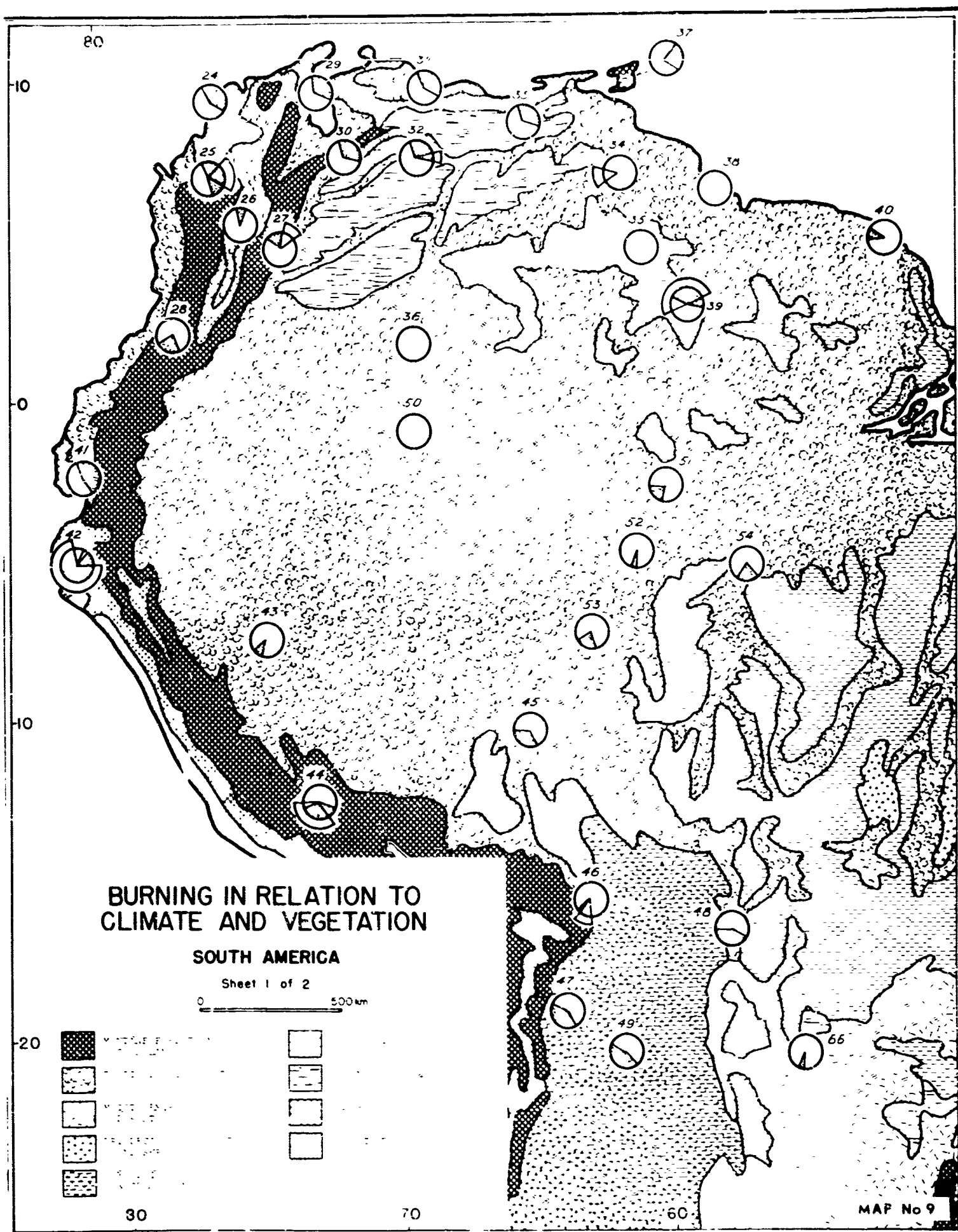
<u>Station Number</u>	<u>Name of Station</u>	<u>Country</u>
1	Tampico	Mexico
2	Ometepe	"
3	San Andres Tuxtla	"
4	Tuxtla Gutierrez	"
5	Merida	"
6	Cozumel	"
7	Flores	Guatemala
8	Amatitlán	"
9	Belize	British Honduras
10	San Salvador	El Salvador
11	Tegucigalpa	Honduras
12	Puerto Cabezas	Nicaragua
13	Bluefields	"
14	San José	Costa Rica
15	Cristobal	Panama
16	Balboa Heights C.Z.	"
17	Habana	Cuba
18	Gibara	"
19	Kingston	Jamaica
20	Port-au-Prince	Haiti
21	Puerto Plata	Dominican Republic
22	Barahona	"
23	Santo Domingo	"



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Map of South America, Sheet 1

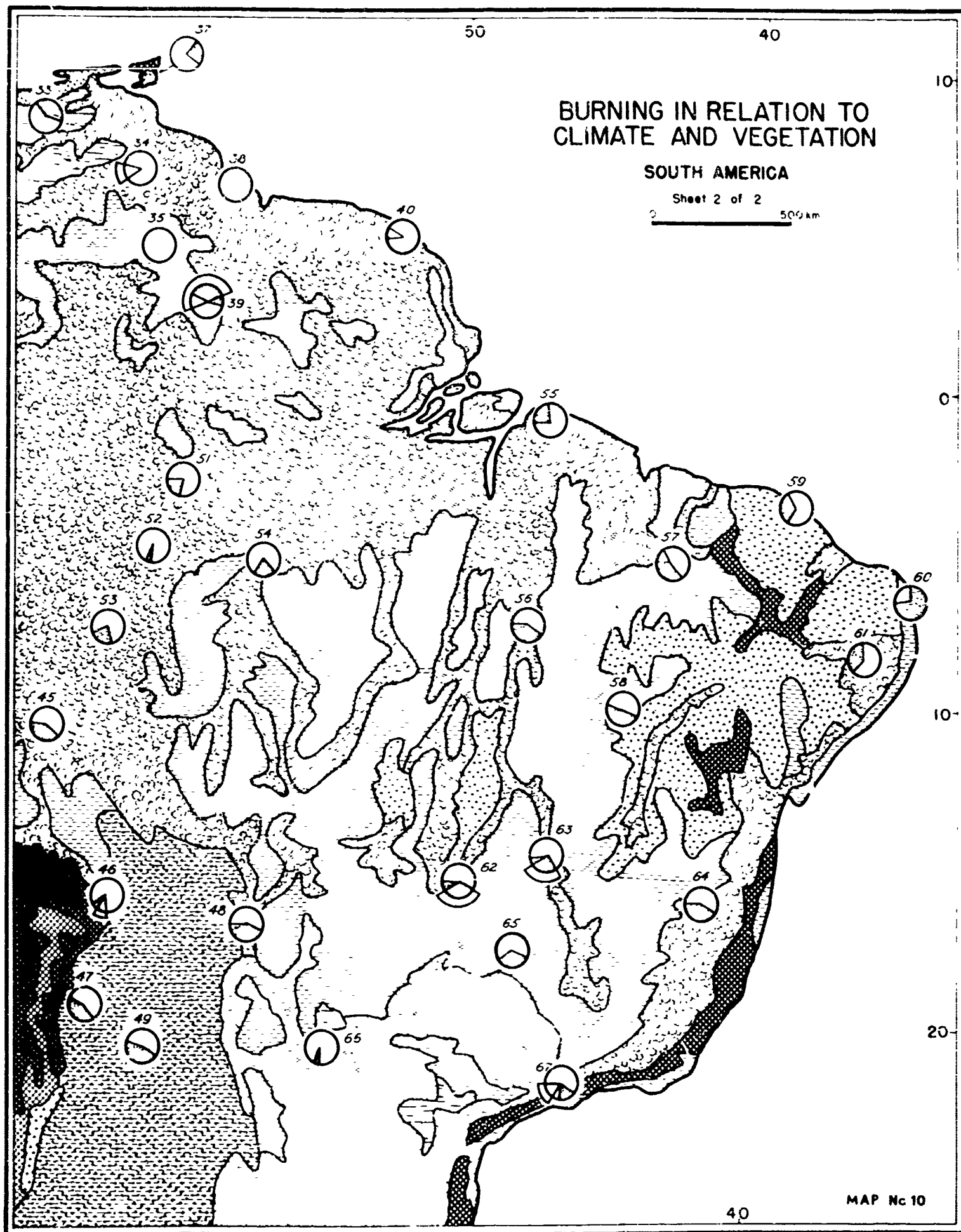
<u>Station Number</u>	<u>Name of Station</u>	<u>Country</u>
24	Cartagena	Colombia
25	Tolu	"
26	Barrancabermeja	"
27	Choconta	"
28	Popayan Florida	"
29	Maracaibo	Venezuela
30	Barinas	"
31	Puerto Cabello	"
32	San Fernando de Apure	"
33	Aragua de Barcelona	"
34	Tumeremo	"
35	Santa Elena	"
36	San Carlos de Rio Negro	"
37	Trinidad	Trinidad & Tobago
38	Georgetown	Guyana
39	St. Ignatius	"
40	Cayenne	French Guiana
41	Guayaquil	Ecuador
42	Piura	Peru
43	Agua Caliente	"
44	Cuzco	"
45	Riberalta	Bolivia
46	Santa Cruz	"
47	Villa Montes	"
48	Puerto Suarez	"
49	Mariscal Estigarribia	Paraguay
50	Sao Gabriel do Rio Negro	Brazil
51	Manaus	"
52	Manicore	"
53	Porto Velho	"
54	Alto Tapajoz	"
66	Bella Vista	"



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Map of South America, Sheet 2

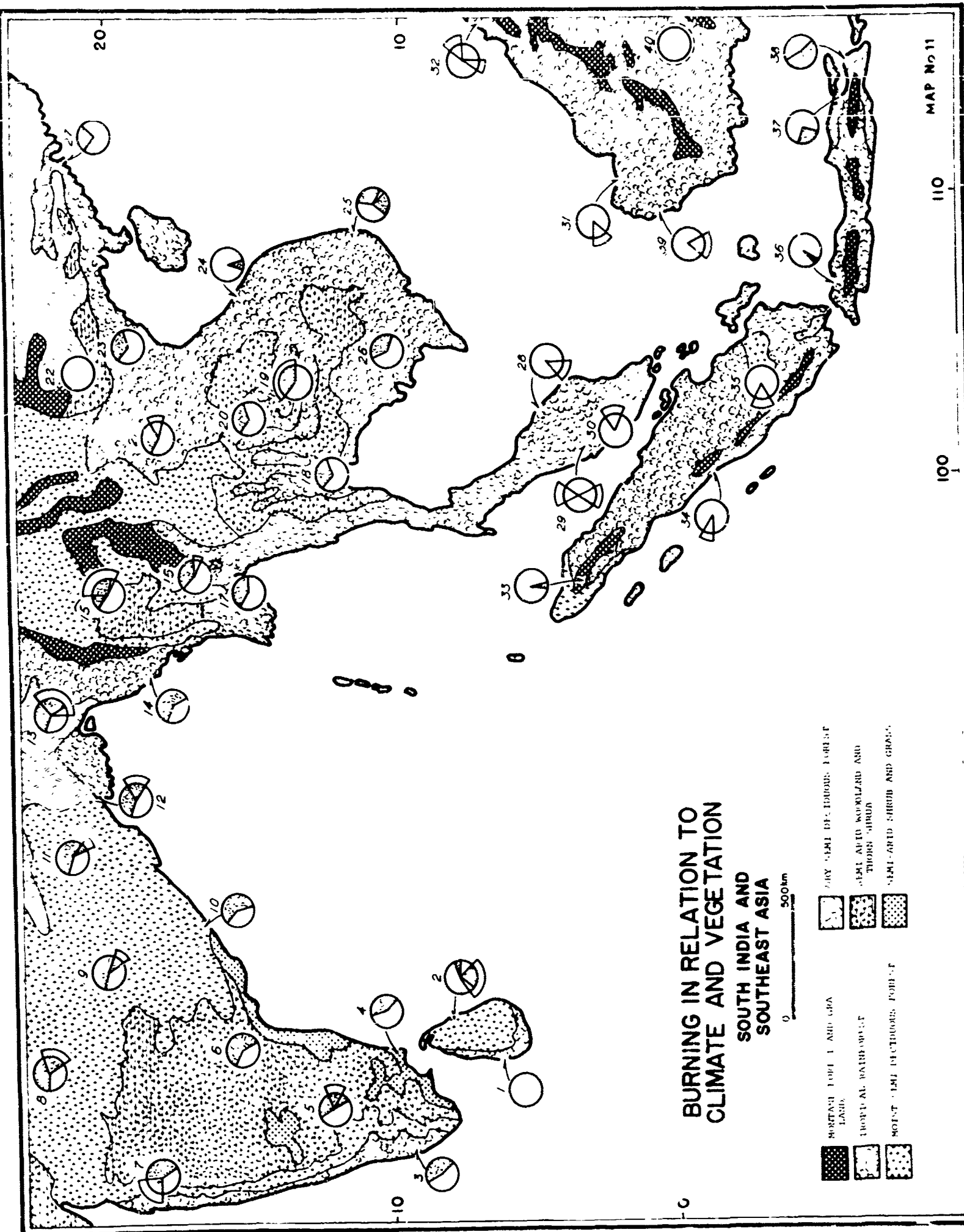
<u>Station Number</u>	<u>Name of Station</u>	<u>Country</u>
33	Aragua de Barcelona	Venezuela
34	Tumeremo	"
35	Santa Elena	"
37	Trinidad	Trinidad & Tobago
38	Georgetown	Guyana
39	St. Ignatius	"
40	Cayenne	French Guiana
45	Riberalta	Bolivia
46	Santa Cruz	"
47	Villa Montes	"
48	Puerto Suarez	"
49	Mariscal Estigarribia	Paraguay
51	Manaus	Brazil
52	Manicore	"
53	Porto Velho	"
54	Alto Tapajoz	"
55	Tracatena	"
56	Carolina	"
57	Terezina	"
58	Santa Rita do Rio Preto	"
59	Mondubim	"
60	Natal	"
61	Pesqueira	"
62	Goiás	"
63	Formosa	"
64	Teofilo Otoni	"
65	Araguari	"
66	Bella Vista	"
67	Itajuba	"



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Map of South India and Southeast Asia

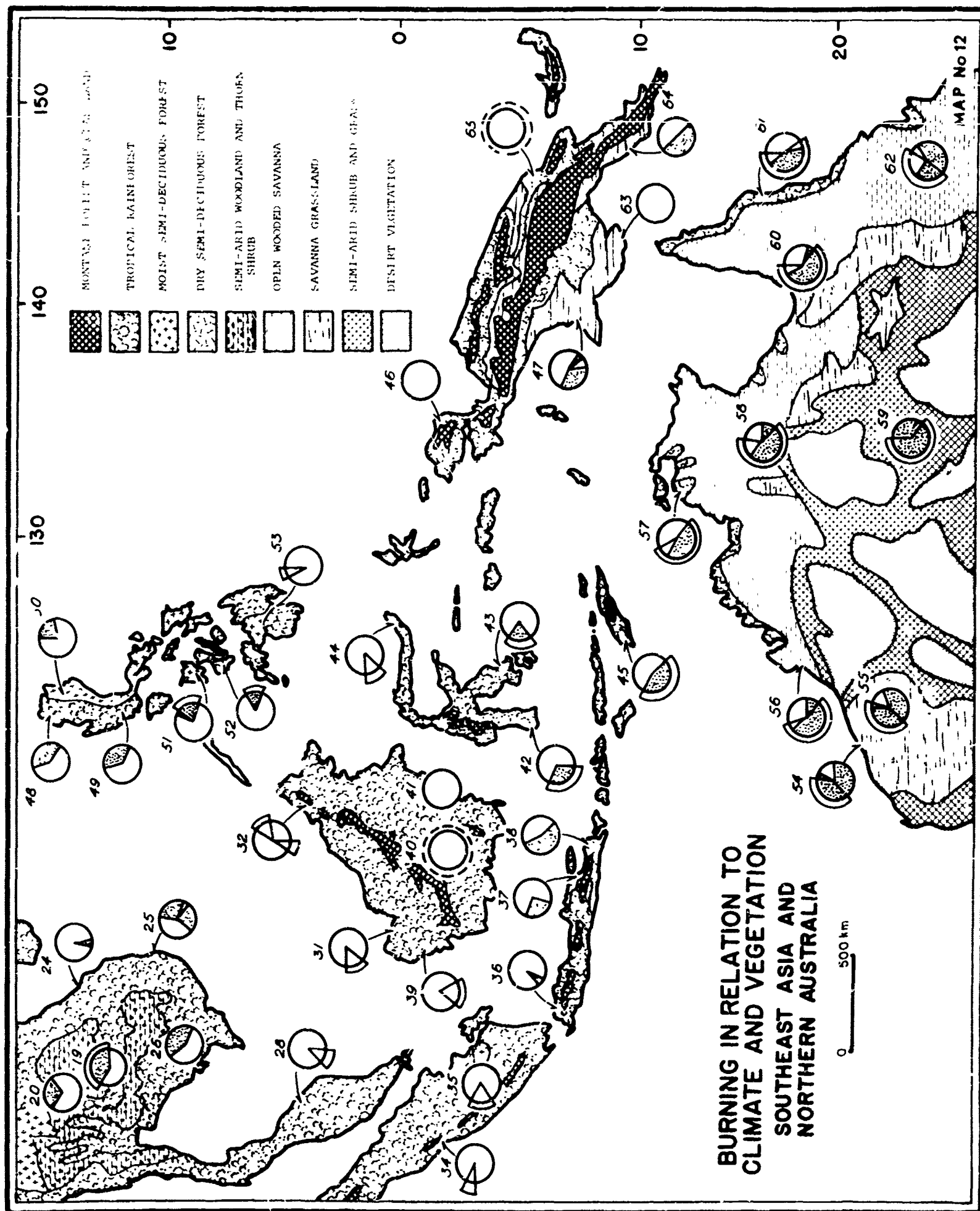
<u>Station Number</u>	<u>Name of Station</u>	<u>Country</u>
1	Colombo	Ceylon
2	Trincomalee	"
3	Cochin	India
4	Negapatam	"
5	Bangalore	"
6	Hyderabad	"
7	Poona	"
8	Bhopal	"
9	Raipur	"
10	Vizianagram	"
11	Ranchi	"
12	Calcutta	"
13	Comilla	Pakistan
14	Akyab	Burma
15	Mandalay	"
16	Toungoo	"
17	Rangoon	"
18	Bangkok	Thailand
19	Surin	"
20	Muang Khon Kaen	"
21	Luang Prabang	Laos
22	Chapa	North Vietnam
23	Hanoi	"
24	Hué	South Vietnam
25	Nhatrang	"
26	Phnom Penh	Cambodia
27	Macau	Macau (Port.)
28	Kota Bharu	Malaysia
29	Kuala Pana	"
30	Kuala Lumpur	"
31	Kuching	"
32	Jesselton	"
33	Takingeun	Indonesia
34	Padang	"
35	Iahat	"
36	Djakarta	"
37	Surabaja	"
38	Assembagus	"
39	Pontianak	"
40	Buntok	"



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Map of Southeast Asia and Northern Australia

<u>Station Number</u>	<u>Name of Station</u>	<u>Country</u>
19	Surin	Thailand
20	Muang Khon Kaen	"
24	Hué	South Vietnam
25	Nhatrang	"
26	Phnom Penh	Cambodia
28	Kota Bharu	Malaysia
31	Kuching	"
32	Jesselton	"
34	Padang	Indonesia
35	Lahat	"
36	Djakarta	"
37	Surabaya	"
38	Assembagus	"
39	Pontianak	"
40	Buntok	"
41	Balikpapan	"
42	Makassar	"
43	Kendari	"
44	Manado	"
45	Kupang	"
46	Manokwari	"
47	Mappi	"
48	Laoag	Philippines
49	Manila	"
50	Tuguegarao	"
51	Iloilo	"
52	Dumaguete	"
53	Davao	"
54	Port Hedland, W.A.	Australia
55	Nullagine, W.A.	"
56	Broome, W.A.	"
57	Darwin, N.T.	"
58	Daly Waters, N.T.	"
59	Alice Springs, N.T.	"
60	Croydon, Qld.	"
61	Crooktown, Qld.	"
62	Emerald, Qld.	"
63	Daru, Papua	"
64	Port Moresby, Papua	"
65	Madang, New Guinea	"



REFERENCES CITED

- Aubréville, A. P. Duvigneaud, A. C. Hoyle, R. W. J. Keay, F. A. Mendonça, and R. E. G. Pichi-Sermolli, Vegetation Map of Africa South of the Tropic of Cancer, Scale 1:10,000,000. Published for L'Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale, with assistance of U.N.E.S.C.O., by Oxford Univ Press, 1959. Explanatory notes by R. W. J. Keay.
- Bartholomew, John (1950) The Advanced Atlas of Modern Geography, McGraw-Hill, New York; Meiklejohn, London, 108 pl. and Index, 47 pp.
- Blanford, H. R. (1925) Regeneration with the assistance of taungya in Burma, Ind. For. Rec., 2, No. 3:81-121.
- Gammon, D. M. (1962) Veld fire control, Rhodesia Agric. Jour., 59, No. 4:177-191.
- James, Preston E. (1959) Latin America, 3 ed., Odyssey Press, New York, 942 pp.
- Phillips, John (1965) Fire--as master and servant: its influence in the bioclimatic regions of trans-Saharan Africa, Fourth Annual Tall Timbers Fire Ecology Conference, Proc., 1965, Tall Timbers Research Station, Tallahassee, Florida, pp. 7-109.
- Rattray, J. M. (1960) The Grass Cover of Africa, FAO Agric. Stud. No. 49, Food and Agric. Org. of the United Nations, Rome, Italy, 168 pp. with map, 1:10,000,000.
- Waibel, Leo (1948) Vegetation and land use in the Planalto Central of Brazil, Geog. Rev., 38, No. 4:529-554.
- Watters, R. F. (1960) The nature of shifting cultivation: a review of recent research, Pacific Viewpoint, 1, No. 1:59-99.

SOURCES OF DATA FOR CLIMATIC SYMBOLS

- C. W. Thornthwaite Associates (1963) Average climatic water balance data of the continents, Part II: Asia (excluding U.S.S.R.), Publications in Climatology, 16, No. 1:5-262, C. W. Thornthwaite Associates, Laboratory of Climatology, Centerton, New Jersey.
- C. W. Thornthwaite Associates (1963) Average climatic water balance data of the continents, Part IV: Australia, New Zealand, and Oceania, Publications in Climatology, 16, No. 3:383-376, C. W. Thornthwaite Associates, Laboratory of Climatology, Centerton, New Jersey.

- C. W. Thornthwaite Associates (1965) Average climatic water balance data of the continents, Part VIII: South America, Publications in Climatology, 18, No. 2:297-432, C. W. Thornthwaite Associates, Laboratory of Climatology, Centerton. New Jersey.
- India Meteorological Department (1943) Climatological atlas for airmen, India Meteorological Department, 100 pp.
- Kendrew, W. G. (1953) The climates of the continents, Oxford, Clarendon Press, 607 pp.
- Trewartha, G. T. (1954) An introduction to climate, New York, McGraw-Hill, 395 pp.
- Wernstedt, F. L. (n.d.) World climatic data, Africa, Dept. of Geography, Pennsylvania State University, 101 pp.
- _____, (1961) World climatic data, Latin America and the Caribbean, Dept of Geography, Pennsylvania State University, 87 pp.

CHAPTER VI

MILITARY ASPECTS OF FIRE IN TROPICAL FORESTS AND GRASSLANDS

A. Introduction

Fires in tropical forests and grasslands are of potential military interest because of their ubiquity, their hazard to men, equipment and materiel, and their effects on the landscape. Therefore, the U. S. Army includes the factor of fire in its requirement for comprehensive and detailed knowledge of tropical physical and cultural environments. This chapter presents selected aspects of fire, derived from the literature survey, that are relevant to the conduct of military operations in tropical areas. Inasmuch as specific requirements can not be anticipated, the emphasis is upon the phenomena, be it the nature of fire itself or its effects upon a given aspect of the environment. The material contained in this chapter has been generated by the literature, and the organization of the material and conclusions derived have been extrapolated from the basic data.

B. Military Aspects of Fire as a Phenomenon

1. Tactical and Logistical Considerations

Certain aspects of fire in tropical forests and grasslands are presumed to be of tactical interest. These include: most prevalent type of fire, fire characteristics and behavior, smoke, and the ability of fire to hold or deny a given area for military purposes.

a. Type of Fire.--Surprisingly, the most prevalent type of fire in the tropics is one of rather low intensity, fed by fuels arranged relatively close to the ground. Regardless of the varying quantities of fuel potentially

present in the major vegetation formations. environmental conditions tend to support only surface fires. Where fuel quantities per unit area are large, such as in tropical forests, the general climatic, microclimatic and biological environments are such as to render fuels essentially non-combustible. Conversely, in the dry margins of tropical wet-and-dry climatic areas, even though climate favors combustion at any time during the year. fuel quantities are low due to low annual rainfall. Conditions favorable to fire occur in areas experiencing a well-defined climatic dry season characterized by rapid desiccation of vegetation, yet receiving sufficient total precipitation to provide a relatively abundant vegetation cover. Some 17.4 million sq. km. (6.7 million sq. mi.) out of a total of 32.4 million sq. km. (12.5 million sq. mi.) of tropical forests and savannas possess conditions favorable to fire of tactical significance. Surface fires are also more significant than other types due to the prevalence of annual burning which reduces fuel accumulations in woodlands and grasslands.

Crown fires and fire whirlwinds, which occur in temperate forests, are rare in the tropics, having been reported only in parts of Australia. Generally, atmospheric conditions during the climatic dry season are not propitious for large scale convection. A tradewind temperature inversion, above which relatively dry air subsides, is present in much of the tropics, and in combination with anticyclonic atmospheric circulation it inhibits cloud development. Although fire-induced cumulonimbus clouds have been reported in Africa, for example, the fires were located in the tropical rainy (Af) and tropical wet-and-dry (Aw) climates of the Congo Basin and southern Sudan.

b. Characteristics of Surface Fires.-- Fire characteristics cannot be predicted accurately because of the number of variables involved. However, field experimentation has isolated the significant factors. They are the intensity of

the fire, which is influenced by the fuel matrix and its spatial arrangement, and the rate of fire spread, which is influenced by local wind conditions, terrain roughness, and the length of time since the last rains.

Surface fires in savanna grasslands are fed by essentially fine-textured grass fuels, generally homogeneous in size, that form a matrix characterized by large surface exposure. Fuels quickly respond to spells of dry weather, so that burning is possible within a week following last rains. Fire moves rapidly through the fuel matrix. Temperatures rise above 850°C (1562°F) some two or three meters (6 - 10 feet) above the ground in the flame front. Generally, single fire fronts are typical of grass fires. Depending on the range of fuel sizes present, the width of the burning zone ranges upwards from as little as 3 meters (10 ft.). Passage of a fire is normally rapid, and reentry of personnel into the burned area can take place almost immediately.

Surface fires characterized by multiple fire fronts, and possibly by fire-brand fires spotted ahead of the general burning zone, are associated with natural vegetation possessing a wide range of fuel types and sizes arranged at various levels above the ground. Multiple-front fires are to be expected in wooded savannas and dry deciduous forest, where there is a diversity of fuels in the vegetation complex. The resulting fires are intense ones in which flame temperatures may exceed 1200°C (2,192°F). Since rates of burning depend in part on fuel sizes, the flame front proceeds through the vegetation irregularly, leaving behind burning areas, smoldering logs and hot embers. Consequently, the width of the burning zone is much greater than in grassland fires. Spotting by fire brands ahead of the general flame front depends on the character of fuels, convection within the burning zone, and prevailing winds. Among the highly inflammable eucalyptus fuels of Australia, spotting 10 km.

(6 miles) ahead of the fire has been observed. Elsewhere in the tropics, spotting is mentioned, but it rarely ignites vegetation more than 2 - 5 km (1 - 3 miles) ahead of the main burning zone.

Fire behavior in wooded savanna and dry forest areas is such that entry into a burned area following fire passage may be delayed for a period of time inimical to military operations. On the other hand, unfriendly forces are also denied entry into such an area.

c. Effect of Fire Passage on Buried Material.--The downward penetration of heat into the soil accompanying fire passage is of both operational and logistical significance. Regardless of the type of fire, a significant increase in soil temperature (greater than 2°C) during a fire has never been recorded deeper than 80 cm. (31.5 in.). Furthermore, the change in temperature is for a limited time, from 2 to 30 minutes. In grassland fires the depth of penetration of heat rarely exceeds 10 cm. (4 in.). Consequently, the impact of fire passage on buried weapons or stored materiel is limited. Of much greater significance than fire to burial of equipment would be the change in soil-water relationships accompanying the wet and dry climatic seasons.

d. Smoke and Visibility.--Smoke is significant in the tropics because widespread burning at the end of the dry season and the low mean altitude of the trade wind temperature inversion favor the concentration of smoke in the lower layers of the atmosphere. Poor visibility due to haze and smoke, both from the air and on the ground, has been referred to frequently in the literature. Bare ground exposed by burning also contributes dust and ash particles whipped into the air by winds. Certain combustion products are highly hygroscopic, and possibly are a significant source of nuclei for the definite increase in atmospheric haze that accompanies smokiness. Poor visibility conditions can persist for weeks. Numerous reports of pilots flying in parts

of South America, Africa and Southeast Asia suggest that visibility often is reduced to less than 5 km. (3 mi.).

The color of smoke is indicative of the type and intensity of the fire. Fires fed by natural vegetation tend to have smoke with visual properties ranging from dense, opaque white to dark tones in which the opacity depends on the size of the fire. Intense fires characterized by high flame temperatures have dark smoke due to the range of fuels being consumed, and a marked increase in carbonized fragments borne aloft.

e. Causes of Unpredicted Fires.--Unpredicted fires in tropical forests and grasslands can be expected to occur; their probability depends on environmental conditions. In savanna areas, fire is possible if a week or two of dry weather occurs regardless of the climatic season. In humid forested environments, fires do not constitute a significant hazard, except where grasslands abut forests. In this case, fire may penetrate a few meters into the forest edge.

Unpredicted fires due to natural causes are relatively insignificant compared to fires set by local inhabitants. Natural causes of fires are limited largely to lightning. However, in the tropics, lightning fires are surprisingly few in number, in spite of the high frequency of thunderstorms. The combination of dry fuels and thunderstorm activity, propitious to lightning fires, is limited largely to the few weeks of shower activity that precede the onset of heavy rains. Fuels are dry enough at this time to sustain fire spread. On the other hand, widespread burning for cultural reasons by this time has usually resulted in removal of readily available fuels, principally grasses, so that the probability of fire is lower than would otherwise be expected.

Man-set fires probably account for more than 97 per cent of all forest and grassland fires in the tropics. These include fires set under measures of precaution and

control as a practical tool in commercial forest and range management. More widespread and frequent are fires set by indigenous peoples engaged in primitive agriculture and grazing. Although fires are not randomly set, control of fires in grasslands is minimal. Accidental fires, due to escape of fire from an area, are common. Pyromania is a significant factor, because the use of fire in many tropical areas is so widespread that no cultural inhibitions exist.

Consequently, all semi-permanent and permanent military installations in tropical areas should consider precautionary measures to ensure safety from unpredicted and accidental vegetation fires.

C. Military Aspects of Fire-Altered Vegetation

Centuries of fire use have transformed large portions of forested tropical areas, experiencing relatively humid climates, into grass and open forest environments. It is here that relatively large quantities of fuel occur in combination with a fairly well defined dry period to produce potentially severe fire. Fires in this type of environment could become sufficiently intense to deter movement of ground personnel and light equipment. Tactical operations dependent on concealment and surprise could be influenced by destruction of the vegetation cover by fire. An approximation of potential fire hazard in relation to climate and natural vegetation can be gleaned by inspection of the various maps found in Chapter V. For example, the area indicated as "derived savanna" on the map of Africa, represents the alteration of an originally continuous cover of tall forest to one characterized by frequent forest relics, open brush and grass areas (see PLATE 6, p. 88, and PLATE 23, p. 140).

1. Recognition Factors

a. Forested Environments.--Certain characteristics of tropical forested environments reveal that fire and clearing have altered the floristic and physiognomic composition

of the communities. For example, the absence of large trees is indicative that clearing has occurred and that the trees present represent an evenly aged stand of successional growth. A dense tangled undergrowth, including large, woody climbers, is characteristic of early stages of regeneration following clearing, fire cultivation, and abandonment of swidden plots in the forest. An altered forest community is indicated by the presence of a large number of species characterized by large broad leaves. The hardness and weight of wood (significant in terms of potential construction materials) depends on clearing and fire. Trees recently reclaiming land tend to be soft and light, whereas old aged trees have hard and heavy wood.

b. Wooded Savanna Environments.--Regardless of how tropical savannas came into being, at the present time most of them are subject to annual fires. Where patches of dense forest appear, they are isolated relics reduced by fire and ax. Within the grassland areas, brush and tree species may have a gnarled, twisted appearance suggestive of vegetation commonly associated with semiarid and arid climates. The physiognomic appearance of these woody plants is due to singeing of branches and coppicing by fires that sweep the area. Incongruous combinations of plant forms, such as tall, large trees with a grass understory also indicate fire, with the trees being the relics of a once extensive forest.

c. Open Grasslands --It is safe to assume that open grasslands are maintained by frequent fire. In most parts of the tropics the natural plant succession is from grassland to various associations of dry and subhumid deciduous forest. Open savannas, recently burned, will exhibit a new flush of ground and shrub cover even though rains may not have occurred. Regeneration occurs due to the ability of plants to draw upon food reserves stored in deep extensive root systems and rhizomes.

2. Concealment and Camouflage

a. Concealment.--Concealment is possible in nearly all types of tropical environment, depending on configuration of terrain and size of operating force. Concealment in forested environments not only depends on the overall physiognomic characteristics of the major types of vegetation but on their areal spacing as well. Furthermore, the nature of the regenerating vegetation following fire, is important. In highly humid forests associated with the tropical rainy climate regeneration of burned areas is so rapid that dense brush may exceed 5 meters (15 ft.) in height in one year, thereby limiting horizontal visibility to a few meters (see PLATE 5, p. 88). Penetration into regenerating areas is extremely difficult due to the density of the rank growth. Passage through a mature forest, however, is not difficult. Under the leaf canopy of the rainforest the undergrowth is sparse, and horizontal visibility may extend from 18 to 35 meters (60 to 110 ft.) It is clear that ease of movement of personnel in forested environments depends on the areal distribution and frequency of regenerating clearings and their stage of development.

The overall character of a forest area that has been subjected to clearing and fire depends also on the cultural practices employed by indigenous peoples. Of importance here is that the average size of clearings may be modest, but depending on the man-land ratio extensive areas of once forested land may be in various cycles of regenerative growth. Such areas should be identified and marked as areas difficult for movement of personnel and equipment (see section F (1) below).

In semideciduous tropical forests where the climate is characterized by a well developed dry season, as for example in the monsoon climate, plant succession on abandoned plots is slower than in rainforest and passes through a greater number of stages. For much of tropical Asia bamboo thickets

and/or tall, coarse grasses reclaim abandoned land. Both successional stages are highly inflammable during the dry season, and severely limit horizontal visibility of ground personnel. Grasses may reach heights in excess of 3 meters (10 ft.), and certain species (Imperata spp.) will burn fiercely even when green. Horizontal visibility in such areas may be limited to less than 1 meter (3 ft.). While movement through grass and bamboo is exceedingly difficult for ground personnel, the value of such areas for concealment should not be overlooked.

Concealment and ease of movement are inversely related in open grassland environments. The diversity in the proportion of low trees and bush to grass in the various types of savanna is such as to make generalizations misleading.

b. Camouflage.--Detailed studies have been carried out with respect to the need and types of camouflage used in the tropics and subtropics. The techniques and requirements of camouflage are not examined here, but certain factors of the environment are noted. The transformation of the natural environment at the onset of the dry season proceeds at varied rates depending not only on the amount of rain that fell in the preceding season, but also upon bioclimatic characteristics of the dominant vegetation, soil-water relationships and availability of ground water. Numerous researchers consider that savannas are edaphic in origin. The combination of heavy impermeable soils and widely fluctuating rainfall seasonally produces severe flooding, followed by rapid water loss largely through evapotranspiration. In some instances sedge lands have been fired, thereby indicating their ability to sustain combustion, even while the surface soil is wet. Consequently, in these areas, where natural vegetation is composed of sedges and low herbaceous forms, one would expect transformation of color to begin early after the onset of the dry season. The succession of changing

color from green to tan would be first the wet sedge lands, second, the various types of grass cover, and finally, the shedding of leaves in savanna bush islands and neighboring forest.

Another important consideration is the lapse of time between fire and the flush of new growth occurring in response to light rains. Savannas are fired near the end of the dry season, largely for cultural reasons. Surprisingly small amounts of rain initiate vegetation response, quickly transforming the blackened land surface to light green. It has been noted in many parts of the tropics that light "dry season" rainfall is sufficient to transform the landscape in a matter of days.

3. Barriers to Fire Spread

The role which various aspects of the physical environment play to prohibit fire spread must be examined within the context of a specific area in which operations are contemplated. A generalized list of types of barriers to fire, such as cliff faces, surface streams, and so forth, has little tactical value in itself. Instead, certain barriers are suggested below, whose tactical importance may not have been given full consideration, but which should be evaluated in the appraisal of the tropical environment. They are: 1) the forest/savanna boundaries, 2) the presence and relative significance of savanna bush islands, 3) the possible significance of relatively narrow bands of pyrophilous vegetation acting as a barrier, and 4) the effects of fauna upon patterns of vegetation, considered in relation to the ability of an area to support fire.

a. Vegetation Barriers.--Vegetation barriers are considered from a different viewpoint than the potential combustibility of a given vegetation environment. In the latter case, for example, tropical rainforest environments are essentially non-combustible. The viewpoint expressed here is the ability of vegetation to halt or damp the fire spread from a fire already in progress.

Much has been written on the sharpness of the forest savanna boundary in many parts of the tropical world. Contrary to what might be expected, the grassland area changes to forest within a distance of a few meters rather than passing through a transitional zone in which the grasses gradually give way to forest (see PLATES 9 and 10, p. 93, and PLATE 21, p. 126). The reasons for the sharpness of the savanna/forest boundaries are not fully understood, but important factors include the fact that grassland fires are low intensity surface fires. The abrupt change in micro-climate and vegetative environment between the forest and the open savanna restricts penetration of any one fire to a matter of a few meters. Where the forest/savanna boundary is sharp, there frequently exists an abrupt change in topography, soils, and edaphic conditions, as well as the ability of the vegetation to carry fire. There is little doubt that the sharpness of the boundary is fire-maintained. Hence, the forest bordering savanna assumes a tactical significance due simply to the abruptness of contrasts across the two environments.

There are many types and subtypes of tropical savanna, whatever may be their origin. Isolated areas of forest surrounded by relatively open grassland have been termed bush or wooded islands. These islands, depending on environmental conditions, vary from areas of low thorn bush and other woody growths not more than 3 to 10 meters (10 to 30 ft.) in height, to relics of a former more extensive humid semi-deciduous forest with trees 30 meters (100 ft.) tall or more. Numerous studies have shown that the various species near the center of large bush islands are not particularly fire-tolerant. These in turn, are encircled by highly tolerant species. The conclusion appears to be valid that fire is unable to sweep to the center of such islands despite the frequency of burning of the grasslands. The military significance of such wooded areas rests not only upon their value as places of concealment, but also on the fact that bush

islands of moderate size are havens from fires sweeping the surrounding grasslands.

The sweep of fire in open grassland savannas is not unlimited, but is contained within the general limits of gallery, palm, and swamp forest communities that occupy perennially wet sites, areas experiencing high water table, or land adjacent to the courses of streams. The spatial distribution of these wooded and forested areas depends on surface and subsurface hydrography. Either the forest communities occupy sites too wet to sustain fire, or the vegetation is fire-resistant. Operational and logistical planning therefore, should consider the tendency of such forests to intercept fires.

b. Bare Ground Acting as a Barrier.--The persistence of bush islands in annually-burned open grassland savannas has been attributed to the trampling of the ground around the trees by domestic livestock and wild game seeking shade during mid-day. The obliteration of vegetation around water holes by livestock and wild game has also been described as extensive. The trampling effect may establish a fire free area 3 km. in radius, as has been noted in parts of Africa during periods of severe drought. Game trails and preferred paths of movement of animals in open grasslands also produce trails criss-crossing open areas which may act as fire breaks in areas where fuels are sparse.

D. Military Aspects of Fire and Surface Conditions

There would appear to be relatively little direct effect of fire upon the soil trafficability of an area in the tropical forest and grassland environments. Studies of the impact of fire upon the physical characteristics of soils indicate that surprisingly little change occurs in the bulk density and soil structure after a fire. Furthermore, frequent and repeated burning may affect soil characteristics that are important to agricultural productivity but would be of no significance in terms of those criteria significant in

determining trafficability (see Chapter III). Of much greater importance would be that of clearing and fire in a forested environment in removing the vegetation cover with resultant increase in runoff, erosion and landslides. The permanent disruption of trails or roads by fire seems less likely except where wooden bridges occur.

E. Military Aspects of Burning Patterns

Two aspects of the patterns of burning need to be examined for their potential military interest: 1) the patterns associated with swidden agriculture in the forested environment; and 2) the patterns of burning and forms of clearing of land in the various savanna environments. PLATE 23, p. 140 and PLATE 24, p. 145 clearly indicate that the amount of area subjected to fire in any one swidden season is very small. Consequently, resulting fires are limited to cleared areas, and their contribution of smoke and other factors significant to military operations resides not so much in what takes place in any one season but what happens to the environment over a period of years. For various reasons, swidden agriculturists may concentrate at forest/savanna boundaries or follow lines of easier ingress into the forest, both of which have tactical significance.

Patterns of burning in woodland savanna, particularly bush islands, are easily identified from aerial photography (see PLATE 21, p. 126). It is also clear that the extent to which uncontrolled fire may cover an area is limited even on relatively level terrain (see PLATE 20, Point A, p. 123). The influence of termitaria on the pattern of burning in wooded savanna has been described in Chapter III. Termite mounds are of two kinds: those that are inhabited and bare of vegetation, and the abandoned ones on which a patch of forest has become established. Both kinds may serve as havens of refuge in fire, either on the mound or in the spear-shaped fire-free area on its lee side.

Burning patterns on savanna grasslands are controlled primarily by the state of the fuel, wind velocity and direction, and topography. In areas of undulating to hilly terrain the pattern of burns tends to occur on downwind slopes and crests of elevated landforms, while intervening vales and hollows escape fire (see PLATE 7, p. 89). In level topography discontinuous and striped patterns can be expected when accumulated fuels are low and wind velocity high. Depending on the driving force of the wind, linear patterns with subsidiary finger-like appendages can be expected (see PLATE 20, p. 123, and PLATES 21 and 22, p. 126). Instructions to ground personnel should include training in recognition of factors affecting patterns of burning and in precautionary techniques to be used in case of fire in various types of environments.

F. Military Aspects of Cultural Use of Fire

The ubiquitous use of fire by the peoples in the tropical world has implications of which military personnel need to be aware in planning tactical operations and logistical support. The purpose of this section is to bring together the cultural variables in the use of fire and to suggest their military significance.

1. Site Selection

The kinds of sites selected by swidden cultivators, nomads, and technologically advanced fire users differ considerably. Swidden cultivators select small patches located with respect to roads, villages, the forest/savanna boundary, soil types, or ecological criteria, such as the type and size of regenerated vegetation, and so forth. The result is that in areas of swidden cultivation the landscape is subdivided into small, irregular patches of open fields, regenerating vegetation, grass, or forest (see PLATE 23, p. 140). Nomadic herders and hunters commonly burn much larger areas than do swidden cultivators. The differences in gross spatial burning pattern have significance in predicting the nature of the landscape that might be an area of military operations.

2. Providing a Supply of Fuel

The presence of a long and severe dry season often makes special measures to provide a supply of fuel unnecessary, since dry savanna grass and brush will burn easily if ignited. Where a humid forest exists, or the dry season is less severe, it is necessary to kill or fell the vegetation so that it may dry out before burning. Thus the cultural practices used in providing a supply of fuel are indicative of the potential combustibility of the vegetation, and can be used as a guide to the expected fire hazard. Felled forest is visible on air photographs. During the forest felling period the area slashed and cut is normally the area that will be burned. However, where the chitemene system is used the area felled is many times larger than the area burned. Thus the extent of cutting is not indicative of the area that later will be burned.

3. Lighting the Fire

The difficulties involved in lighting a fire in humid forest, and some of the techniques used to overcome them, are discussed in Chapter IV. It has been observed that even flame throwers are of little value in igniting uncut moist Malayan forest. However, the change in forest microclimate that results when the trees are lopped or felled vastly increases the potential combustibility, and hence the fire hazard, even of tropical rainforest. Thus the contrast between felled and undisturbed forest has significance from the standpoint of havens of refuge, storage of vehicles and equipment, and troop bivouac. A similar contrast in combustibility exists in areas of the forest/savanna mosaic between the savanna grasses and the patches of relict or galeria forest scattered within it.

4. Fire Control

Many authors have noted that measures to prevent fires, confine their spread, or reduce their severity exist even among the most primitive users of fire. Swidden culti-

vators often leave a green fire break of forest around their villages and swidden plots. Nomadic pastoralists as well as technologically advanced peoples burn fireguards to reduce the danger of fire spread. The adoption of such indigenous fire control techniques by United States personnel offers a useful and low cost means of temporary reduction of fire hazard. The use of more sophisticated fire fighting and fire control equipment and methods, such as those described in Chapter IV, may be justified by the size of operation contemplated.

5. Cyclical Patterns of Burning.--Except for the areas of tropical rainforest where it may occur at practically any time, burning in the tropics occurs regularly according to an annual cycle. Various burning periods have been discussed in Chapters IV and V and illustrated on maps. The military significance of cyclical burning lies in its predictability in time, if not in place. In areas where swidden cultivation or nomadic grazing is the way of life, the people will burn when the annual burning period arrives, since it is an inherent part of their economy and cultural tradition. Therefore, the seasonal increases in fire hazard, smoke, haze, reduced ground visibility, and other hazards referred to above may be planned for in advance.

6. Population Distribution.--The military significance of population characteristics is primarily in their relationship to the geographic location and incidence of fire. For example, in South Asia and Southeast Asia the river valleys and coastal plains are settled by dense populations cultivating paddy rice, and are rarely burned. Nomadic pastoral activities are rare. The area under swidden cultivation is primarily confined to the uplands and hills, where the population density is comparatively sparse. In Latin America and Africa on the other hand, where intensive agriculture is unusual, and extensive pastoralism and swidden cultivation are widespread, fire may be expected to occur much more widely, even in areas settled by people of European descent.

Another element is the migratory nature of swidden agriculture. The cycle of migration varies in length, but the maximum time that one forest patch is cultivated is usually three years. Therefore, older maps and aerial photographs may be of questionable reliability in terms of their depiction of land use and vegetation cover.

7. Fire and Aerial Photography.--Aerial photography is of great potential value, from both the tactical and logistical standpoints, in evaluating the characteristics of tropical areas subject to burning. Soil and vegetation associations can be identified on the photographs after sampling studies have been carried out on the ground. If information about the time of burning, the quantity and type of fuel present, and recent meteorological information are brought to bear on an area, an up-to-date assessment of fire danger, expected fire intensity, recommended fire control measures, and location of havens and barriers to fire spread could be provided to field commanders.

Cultural features related to fire may also be located on aerial photographs. By pointing out sacred groves, fetish trees, wooded burial places, swidden plots in various stages of regrowth (see PLATE 23, p. 140), paths and tracks leading to swiddens, ponds, streams, and villages, needless damage to the feelings of the indigenous population may be avoided.

The quality of aerial photography may be affected by smoke and haze during the fire season. Loss of definition, changes in tone and blurring of shadows may occur. Consequently, problems of establishment of photo identification keys, target identification, and evaluation of trafficability may develop. Infra-red photography may be of value in identifying recently burned areas and creeping subsurface fires in forested areas. Further research is needed to develop more fully the capabilities of aerial photography and remote sensing techniques in relation to fire in the tropical forests and grasslands.

APPENDIX I

SEARCH FOR A REALISTIC MODEL OF FIRE-FRONT PROPAGATION¹

The search for knowledge about fire is complicated by the fact that the number of combinations of physical circumstances producing an accidental fire is almost infinite. Chemical kinetics, fluid mechanics, heat and mass transfer enter and interact in such varied ways as to make difficult any meaningful generalized statement about their relative significance.

Transport Phenomena and Propagation Principles

All fires involve transport of energy, mass, momentum. To indicate the nature of these transport processes as they apply particularly to fires, and the way such processes interact, the problem of how a fire moves through a forest is chosen. This serves both to illustrate the approach to quantitative treatment of steady fire-front propagation and to illustrate some of the other factors relating to fire problems.

Consider fire moving through a forest, forming a fire front of great length; let the problem be to formulate a mechanism of spread which is near enough to reality to predict reasonably good answers to such questions as how fast the flame front is moving, how much a change in wind velocity or air humidity would affect the speed, how wide a firebreak or how much water application is required to stop it. The problem is so complex as to seem beyond analysis at first, but certain assumptions can be made which although over-

¹. Adapted from National Academy of Sciences, N.R.C., A study of fire problems, Washington, D. C., 1961, 176 pp.

simplify the nature of the problem do permit an approach toward solution.

Consider fire spread in the forest litter. Flame is creeping forward in response to several mechanisms. The fire front is the burning zone, extending from the locus of ignition to the depth where combustion intensity is too weak to affect the leading edge. The burning embers are warming the adjacent unignited elements by radiative transport which may be treated as normal to the ignition surface in the litter, if the reach of this radiation is small relative to the depth of the litter. Assume that the complex of flame and burning embers behind the ignition surface radiates like a black body at an assigned flame temperature T_F , the radiative flux to any element dx , a distance x ahead of the ignition surface can be readily calculated if an adequate quantitative description of the litter is available (see Fig. 1). For later reference let this energy rate per unit of ground area be designated $q_1(x)$.

Added to the horizontal radiative transport is a convective energy transport, consequent on the fact that twigs and needles find themselves in the path of gaseous combustion products rising or being blown sideways from burning elements. The reach of this mechanism in litter is also small, and could become negligible in response to the action of inflowing air preventing any unignited elements from lying in the path of the combustion products. Still a third mechanism, of unknown importance, is the explosive ejection of gas jets, associated with rupture of a wall entrapping evolved gas. The mathematical expressions of these mechanisms

¹Any quantitative consideration of fire propagation must be preceded by a quantitative description of the fuel complex. The total fuel mass per acre, its total surface area, the distribution of mass and surface with height (to account for multistoried vegetation) and distribution function representing the randomness of placement of fuel at various levels, are all of prime importance.

are represented by functions (1) and (2) which are taken up later.

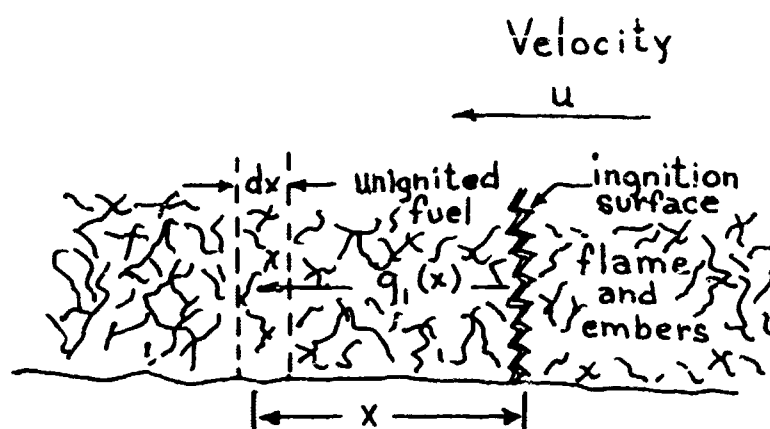


Figure 1. Structure of fire propagation in forest litter.

The problem now arises of coupling heat transfer into the unburned fuel with the ignition process, which is itself intimately related to the chemistry of wood pyrolysis and the chemical kinetics of combustion. For the present purpose the chemical details can be isolated for separate treatment by postulating that ignition occurs when the fuel reaches a certain surface temperature T_i or has absorbed energy of a certain magnitude Q_i , sometimes referred to as the critical ignition impulse, where T_i and Q_i are treated as properties of the fuel under consideration. This is certainly not true; T_i or Q_i depends on the wood thickness and on the heating schedule. Consequently it is necessary to estimate the value of Q_i , use it in calculating the propagation and, if necessary, to iterate. One thus achieves an important simplification of the fire-spread problem by separating it from the ignition problem, which can more effectively be studied by itself in the laboratory.¹

¹This decoupling of two problems at a point where their interaction is weak is an important and very necessary trick in achieving any answer to so complex a problem as fire spread. Nowhere is there a suggestion that the element decoupled lacks importance to the ultimate objective.

With the flame front defined as a locus of build-up of the thermal impulse into the litter to the value Q_i , it is possible to formulate the first statement about the fire front. With the x-coordinate representing distance from the fire line and negative values of x located in the unignited fuel,

$$Q_i = \int q dt = \frac{1}{u} \int_{-\infty}^0 q dx, \quad (1)$$

where u is the velocity of the flame front and q is the total heat-transfer rate to fuel by all mechanisms, per unit of ground area (unit length along the fire line is the basis of calculation). u here has been assumed constant for simplicity; in fact, during fire build-up or firebreak jumping, u will not be constant and must be left inside the integral. Further progress must await discussion of the factors contributing to q. Although there may not be enough flame above the litter to make flame radiation downwards and towards unignited fuel important, there is significant irradiation of the litter by other flames from the burning brush. Within this brush there is forward movement of heat from the flame by a process of convective action-at-a-distance. The fine structure of the wind is such that an eddy of flame or of partially ignited gas mixture may be moved forward a distance x, where it bathes a twig or branch and transfers heat to it in proportion to the difference between flame temperature T_F and local twig temperature T; and the chance that this will happen is a sensitive function of wind structure (spectrum of turbulence), mean wind velocity V_w and, particularly, the distance from the flame front. The chance, of course, goes down rapidly with increasing x. This transport term, energy flux per unit ground area, then takes the form

$$q_2 = \left[f_2(x, \text{flame height}, V_w, \text{wind structure}) \right] (T_F - 1) \quad (2)$$

where the function f_2 depends on fuel type.

A transport mechanism varying greatly in importance in different fire types is that of ignition by firebrands ahead of the continuous burning zone. There are many small islands of flame far ahead of the main front, irregular, large islands near it, and peninsulas formed by recent merging of islands with the continuous ignition line. It has been suggested that the mathematics of epidemic propagation is applicable, with its analogues to the varying potential of firebrands to serve as igniters, the varying sensitivity of the forest areas to respond; but with an added factor of sensitivity increasing with the preheat caused by the approaching fire.

The need for adding the radiative transfer from brush flames to the other mechanisms which operate to bring the litter to its ignition point produces realization of an important feature of fire spread, the interaction of fire in different levels. There is one problem of evaluating fire spread in the litter, with a term included which represents interaction between litter and brush. There is another problem of evaluating fire spread in the brush, with a term representing inter-action between brush and litter and another between brush and tree crowns, since the crowns will send up high flames, the radiation from which is a major contributor to spread. There thus emerges a picture not of a single front moving forward but of two or perhaps three, of markedly different structure, each propagating forward as a result of the combustion of fuel in its own level of the forest and of the transfer into it of heat from other levels. From a mathematical point of view, the propagation of this compound fire front can be described by three systems of equations which are coupled by terms representing the exchange of heat between the layers. In principle such a set of equations can be solved together. In some situations there will not

be a sufficient supply of heat to one or other level of the fire, and combustion will stop altogether in this level although it may continue in the remaining level or levels. Thus in a forest with a clear floor level and with dry foliage, a fire may crown and race ahead without damaging the lower levels at all. In the evening, as the humidity increases and temperatures fall, the fire may drop out of the crowns because it no longer generates sufficient heat, and it burns quietly in the lower levels with only occasional crowning and damage of the foliage of larger trees. Recognition of coupled levels of flame propagation is of great importance in the design of model experiments.

With the major mechanisms of energy transport identified, there remains for consideration the source of that energy, the burning process. Consider a brush fire, with the fuel packing sufficiently dense to suggest that much of the process of completion of combustion occurs in the flames above the brush. Take the local burning rate, or fuel weight loss per unit ground area lying behind the ignition line, to be directly proportional to the local rate of heat absorption by the fuel on unit ground area. As the char thickens on the larger fuels the accumulating thermal resistance will cause reduction in the gas-evolution rate of a level incapable of flame support. For simplicity the gradual loss of proportionality assumed above will be replaced by a sudden cutoff; and combustion, at least insofar as it affects flame spread, will be assumed to cease when a definite fraction α of the initially available fuel has been consumed. This is the locus of the back of the burning zone.

The gas evolved by the mechanism just described burns in a buoyant flame, and the progress of combustion, the shape, the temperature, and the concentration pattern in the flame, are determined by the dynamics of the gas flow. The irradiation pattern on the fuel can now be calculated or estimated,

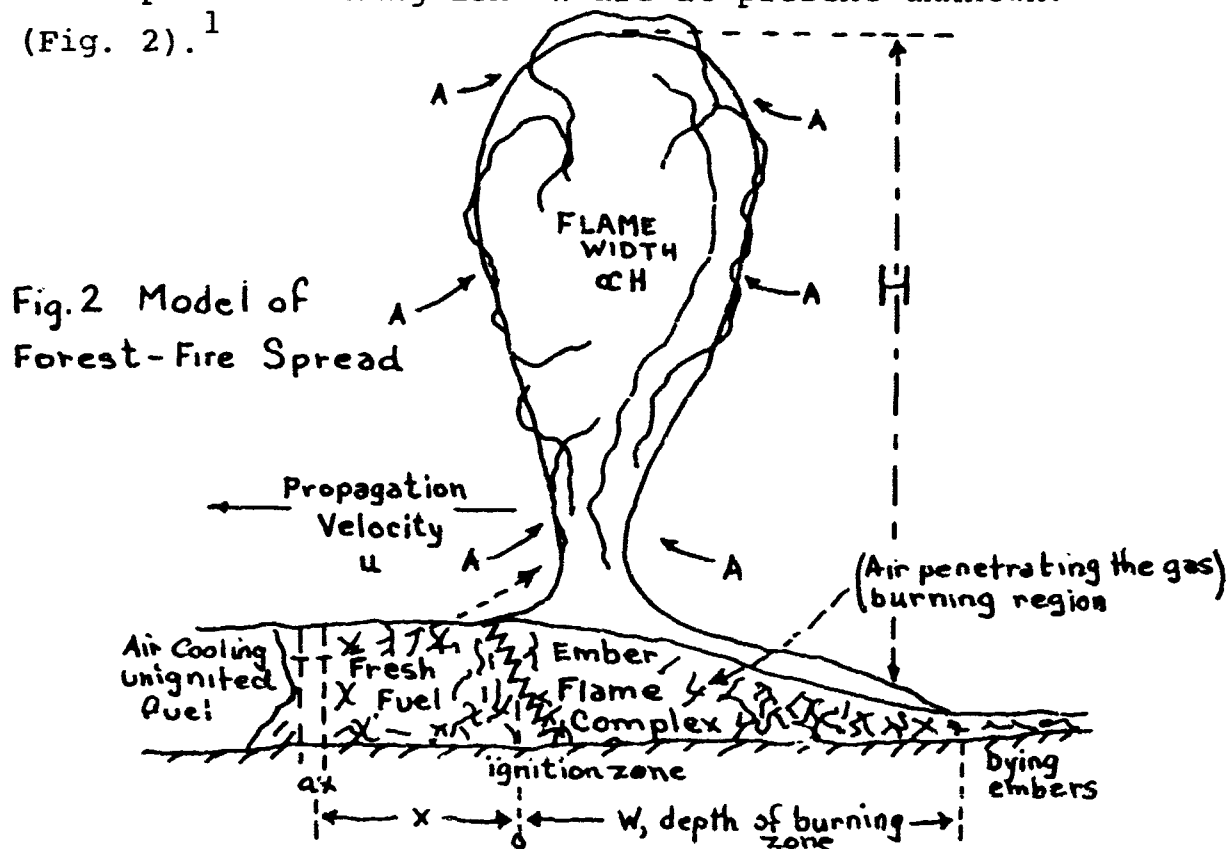
provided that sufficient information is available on the pattern and strength of the external wind, and its effect on the flame shape.

The coupling is now complete, i.e., all the elements of a chain of interactions have been described, and a quantitative formulation of them will permit a solution of the propagation problem, including the velocity.

Now that certain statements have been made concerning fire propagation in the forest litter, it becomes possible to formulate a fire model in a semi-quantitative way.

Consider the steady advance of a long straight flame front at speed u through the brush, and take a coordinate system with the origin at the locus of ignition of the fuel and the x -axis in the direction opposite to that of propagation. The front speed u , the flame height H , and the depth of burning zone W are at present unknown.

(Fig. 2).¹



¹The fuel used in the model is visualized as dense brush representing a relatively homogeneous fuel complex of limited depth.

Focus attention first on the unburned fuel ahead of the ignition zone, and accept the assumption previously discussed that ignition occurs when the cumulative flux into the fuel associated with unit ground area reaches Q_i , the critical ignition impulse. The accumulation of energy in the fresh fuel is assumed to be due to the following terms, all in units of energy-reception rate by the fuel on unit ground area:

$q_1(x)$ is the more or less horizontal flux from the ember-flame matrix behind the ignition zone through the distance x to the fuel. The radiating matrix is taken as a black radiator at flame temperature T_F , assumed known. The absorption by the fuel in width dx is then

$$q_1 = B \sigma T_F^4 e^{-ax} a dx \quad (3)$$

where B is the height of the ember-flame matrix, assumed to be brush height; a is the reciprocal mean free path or projected area per unit volume of intervening brush; σ is the Stefan-Boltzmann constant. To justify treating the source as black, the burning zone w must be thick compared to the mean free path $1/a$; and to justify ignoring losses up through the top of the brush, the brush height B must also be large relative to $1/a$.

$$q_2 = \left[f_2(x, H, V_w, \text{wind structure}) \right] (T_F - T) \quad (4)$$

is function (2) previously described, and represents convection due to flame transport. V_w is the wind velocity and experimentation is needed to establish a suitable form of this function.

$q_3(x, H, V_w)$ is the downwardly directed radiative flux from the over-head flame, dependent on the composition of the gaseous products of pyrolysis feeding the flame and on the distribution, in space, of temperature and radiator composition. There is evidence that, for a fixed gaseous fuel

type and in the absence of wind disturbances, radiation from the flame plume is uniquely determined by H.

$$q_4 = \left[f_4(V_w, H) \right] (T_a - T) \quad (5)$$

is the convective cooling of the heated but not yet ignited fuel by air flowing through it.

The accumulation of energy to produce ignition may be formulated

$$Q_i = \int_{-\infty}^0 q(x, H, V_w, T) \cdot \frac{dx}{u} \quad (6)$$

where $q = q_1 + q_2 + q_3 + q_4$

Consider now the burning zone where the pyrolysis which feeds the overhead flame is occurring, and which is assumed to proceed at a rate proportional to the local input of energy. This input is provided by the overhead flame radiation q_3 and by local burning of some of the embers where fresh air reaches into the zone. Call the latter input $q_5(V_w, H)$, indicating its dependence on the external wind and on the induced wind that is related to H.

The heat of combustion q_G of the gas evolved, or loss of chemical enthalpy of the fuel, is assumed to be proportional to the input energy flux $q_3 + q_5$. Thus

$$q_G = \beta (q_3 + q_5) \quad (7)$$

Furthermore, this energy evolution in gaseous form from the fuel is assumed to continue until the fraction α of the total heat of combustion Q_c of fresh fuel has been evolved. At this stage active burning ceases. This gives

$$\int_0^W q_G \frac{dx}{u} = \alpha Q_c \quad (8)$$

Combining these relations gives

$$\int_0^W \left[q_3(x, H, v_w) + q_5(H, v_w) \right] dx = \frac{\alpha}{\beta} u Q_c \quad (9)$$

where the fire velocity u has been assumed constant.

There remains the problem of relating H with the other variables. Theory, supported by experiments, show that the height of a flame is proportional to the two-thirds power of the gaseous fuel feed rate, provided negligible momentum is brought in by the gas. Applying this to the present situation gives

$$\int_0^W q_G dx = \gamma H^{3/2} \quad (10)$$

where γ is a proportionality constant and hence

$$\int_0^W (q_3 + q_5) dx = \frac{\gamma}{\beta} H^{3/2} \quad (11)$$

Equations (6), (9), and (11), together with knowledge of the forms of the five q -functions, would constitute the complete set in the variables u , H , and W if the local temperature T of fuel ahead of the fire were not involved in the integrand of equation (6). A reasonable approximation could be obtained by using some estimated functional form for $T(x)$ running from T_a to T_{1g} . Rigorous treatment would involve a study of unsteady heat flow in the fuel, leading to a family of curves relating fuel surface temperature to heat impulse Q for different values of heat input rate. It would then be possible, using stepwise integration from far ahead of the flame to the ignition locus--all based on an assumed flame height and heating schedule of the wood--to evaluate the integral in equation (6), combine it with (9) and (11) and obtain a solution. The process would require

iteration, and is to be avoided by replacement by some such approximation as that suggested.

Clearly this is a tentative model requiring further development and calling for supporting experiments.

APPENDIX II

PROBLEMS IN THE CLASSIFICATION OF TROPICAL FORESTS AND SAVANNAS

Generally, three main criteria are evident in the various classifications of tropical vegetation and in the descriptive names employed to designate certain vegetation types. In addition to location, there is habitat or environment, physiognomy and floristics. Unfortunately, knowledge of tropical vegetation does not permit a classification based on the relationships between vegetation and its habitat. The principal reasons are that the technical problems of description (physiognomy) and identification (floristics) are so great, that little progress has been made toward relating these characteristics to effects of climate, soil and other living organisms on the vegetation.

Some of the problems involved in classifying tropical forests are:

- 1) determination of representative area;
- 2) criteria necessary for correct choice of stand because of the great richness of the tropical tree flora.

Wyatt-Smith, according to Poore (1963), has recorded in the Malaya mixed Dipterocarp forest (rainforest) 2,366 individuals belonging to 444 species in 11 acres of forest belonging to two types. This is an average of only 5.3 individuals to each species. Poore continues by doubting the "homogeneity" of the enumerated sites.

- 3) meaningful description of an area in which there are no dominants;
- 4) subdividing tropical formations into units that are smaller and more precise than the

generally agreed upon larger units determined by gross climatic or edaphic differences.

A most important question, as yet unanswered is to what extent is tropical forest a climax formation. Many investigators believe that most humid tropical forest, appearing undisturbed, is actually mature second growth.

Hills (1965) in reviewing major research problems associated with tropical savannas includes a most useful listing of descriptive terms for vegetation types classified or mapped as "savannas", drawn from investigation of the literature. The list is reproduced below.

ENGLISH

semi-deciduous tropical forest	semi-deciduous woodland
caatinga xerophilous forest	tall mesophytic grassland
cerrados subtropical forest	open savanna
savanna woodland	palm savanna
low tree savanna	pine savanna
ceradão	shrub/grass savanna
low-layered forest	savanna grassland
high grass/low tree savanna	campo limpo
orchard savanna	tall grass savanna
savanna parkland	bunch-grass savanna
tropical deciduous xerophytic	steppe
woodland	steppe grassland
campo cerrado	low grass savannas
caatinga	tussock grassland
dry mixed forest	open seasonal grassland
bushveld	desert grass savanna
subtropical bush	high-grass savanna
open grass woodland	sedge savanna
	Acacia desert-grass savanna

FRENCH

savane forestière	savane garrigue
savane boisée	savane herbeuse
savane arborée	savane macrécageuse
savane arbustive	savane inondable
savane arbustive riche	savane steppique
savane arbustive pauvre	savane pseudosteppe
savane hallier	

Numerous classifications of savanna vegetation have appeared in the literature. A table comparing selected classifications of savanna vegetation appears below and is also drawn from Hills (1965).

TABLE I
Selected Classifications of Savanna Vegetation¹

Author	Woodland and/or forest type	Parkland type	Grassland type	Shrub type
Beard ²		tall bunch- grass savanna: open savanna orchard savanna palm savanna pine savanna	short bunch- grass savanna sedge savanna	
Brazilian ³	cerradão campo cerrado	campo cerrado	campo limpo	campo sujo
Williams ⁴	woodland: low-layered forest low-layered woodland	tree savanna low tree savanna	tussock grassland	savane herbeuse
Aubréville ⁵	savane boisée	savane arborée	savane herbeuse	savane arbustive
Trochain ⁶	savane forestière	savane arborée savane verger savane palmeraie savane bambousaie	savane: savane steppique savane marécaguese savane inondable	savane arbustive
Shantz ⁷	high grass/ low tree savanna	Acacia tall- grass savanna	Acacia desert- grass savanna	
Cole ⁸	savanna woodland	savanna parkland	savanna grassland	low tree and shrub savanna
McGill University Savanna Research Project	savanna woodland	open savanna woodland	herbaceous savanna: grass dominant sedge dominant	shrub savanna

- ¹Several authors, e.g. Cole, include in their classification 'Thicket and scrub'. This category has value for vegetation associations found within or adjacent to savanna regions that are best categorized in this way.
- ²Beard, J. S., "The Savanna Vegetation of Northern Tropical America," Ecol. Mon., XXIII (1953), 213.
- ³This is a widely used and acknowledged classification that is frequently used in English language texts.
- ⁴Williams, R. J., "Vegetation Regions," in Atlas of Australian Resources (Canberra, 1955), map and explanatory notes.
- ⁵Aubréville, A., Etude écologique des principales formations végétales du Brésil (Centre Technique Forestier Tropical, Nogent-sur-Marne, France, 1961).
- ⁶Trochain, J. L., "Nomenclature et classification des Milieux, Végétaux en Afrique Noire Française," Comp. Rendus Cong. Int. Bot. 8th, sec. 7 (Paris, 1954), pp. 106-11.
- ⁷Shantz, H. L., and C. F. Marbut, The Vegetation and Soils of Africa (Am. Geog. Soc. Res. Ser., 3, New York, 1923).
- ⁸Cole, M. M., "Vegetation Nomenclature and Classification, with Particular Reference to the Savannas," S. Af. Geog. J., II (1963), 10.

APPENDIX III

CORRESPONDENTS LISTED IN THE BIBLIOGRAPHY

- Aitken, W. Ernest (1964) Cities Service Petroleum Corporation, Bogotá, Colombia.
- Arnold, Keith (1964) Director, Forest Research, Forest Service, U.S. Dept. of Agriculture, Washington, D.C.
- Arrieta P., Oscar (1964) Empresa Petrolera Fiscal, Oficina de Lima, Mesa de Partes, Lima, Peru.
- Birbragher, Leon and Isaac Sredni (1965) P.O. Box 4363, Bogotá, Colombia, (Interview).
- Chacon, Rene Prieto (1965) Director General Forestal, La Paz, Bolivia.
- Chief Conservator of Forests (1965) Ministry of Agriculture, Forests and Wildlife, Forest Division, Pamba House, P.O. Box 426, Dar es Salaam, Tanzania.
- Clarkson, James (1965) Dept. of Geography, University of Hawaii, Honolulu, Hawaii, (Interview).
- Cockbill, Gerald F. (1955) Office of the Director, Tsetse Fly Operations, P.O. Box 8100, Causeway, Salisbury, So. Rhodesia. (Letter to H. H. Bartlett).
- Corenjo, Francisco (1964) Department of Forests and Soils, Ministry of Agriculture, Republic of Panama.
- Espinal, Augustin (1964) c/o Director General Forestal, Secretaria de Estado de Agricultura, Santo Domingo, Dominican Republic.
- Esso Standard Oil, S.A., Ltda. (1964) Refineria Esso, Managua, Nicaragua.
- Furress, C. K. (1965) Forestry Commission, P. O. Box 8111, Causeway, Salisbury, So. Rhodesia.
- Gardner, T. A. M. (1965) For AG Chief Conservator of Forests, Forest Department, P.O. Box 30513, Nairobi, Kenya.
- Giffard, P. L. (1965) Conservateur des Eaux et Forêts, Service des Eaux, Forêts, et Chasses, Parc Forestier de Hann, B. P. 1831, Dakar, Sénégal
- Guevara, J. M. (1964) Universidad Central de Venezuela, Facultad de Humanidades y Educación, Escuela de Geografía, Caracas, Venezuela.

- Hickey, M. J. (1964) Operations Manager. Sinclair & B. P. Colombian, Inc. Apartado Correo 3459, Bogotá, Colombia.
- Holsoe, Torkel (1964) Forestry Specialist, U.S.A.I.D., Av. España 386, Lima, Peru.
- Krause, Annemarie (1965) Associate Prof., Dept. of Geog., Southern Illinois Univ., Carbondale, Illinois, 62903.
- Lowe, John (1964) Student in School of Theology, Boston University, Boston, Massachusetts. Former missionary in So. Rhodesia.
- Mirandar, Luis E. (1964) Chief of Division of Agro-economics, Managua, Nicaragua.
- Overholt, Dr. William (1963-64) Chaplain, Boston University, Boston, Massachusetts. (Interview).
- Popenoe, Hugh (1964) Assistant Prof. of Soils, Director Caribbean Research Program, U. of Florida, Gainesville, Florida.
- Rattray, J. M. (1964) Matopos Research Station, Private Bag K19, Bulawayo, Southern Rhodesia.
- Richards, P. W. (1965) Professor of Botany, University College of North Wales, Memorial Building, Bangor. Wales, Great Britain.
- Secretary of Forestry, Department of Forestry, Gebouoranje-Nassau Building, Schoemanstraat 188 Schoeman St., Pretoria, Republic of South Africa.
- Sherry, S. P. (1965) Chief Silviculturist, Wattle Research Institute, U. of Natal. Pietermaritzburg, So. Africa.
- Smart, J. B. (1965) Forest Department, P.O. Box 30513, Nairobi, Kenya.
- Thompson, C. K. (1965) Director of Conservation and Extension, Department of Conservation and Extension. Ministry of Agriculture, P.O. Box 8117, Causeway, Salisbury, So. Rhodesia.
- Vandermeer, Canute (1965) Assist. Prof., Dept. of Geog., Univ. of Wisconsin-Milwaukee, Milwaukee, Wisconsin, 53211.
- Wise, Harry (1965) 3930 SW 6th Place. Gainesville, Florida.

SELECTED BIBLIOGRAPHY

The bibliography contains references largely more recent than 1920, and relating directly to the interaction of fire and the environment. To facilitate its use, the bibliographic references have been grouped into broad geographic areas and listed alphabetically. They are further identified as to location by country included within the broader geographic area.

There are two sections to the bibliography. The location and content of each reference in Section I is indicated by a series of Arabic numerals, Roman numerals, and letters set off from the end of the reference by parentheses. References in Section II are identified by their geographic location only.

The classification system used is presented before the main body of the bibliography. The following examples illustrate and explain the arrangement of the classification numbers and letters:

A. Sample reference Section I - fully classified.

Budowski, Gerardo (1951) Los Incendios Forestales en Venezuela, Agr. Venezol. 16, No. 155:24-28.
(255: I 2: III C 0: III D 0: III E 0,1: III G 0,1).

- | | |
|-----------|---|
| 255 | refers to the geographic location, in this case Venezuela. |
| I 2 | refers to the appraisal of the reference. |
| III C 0 | refers to the effects of fire on rates of runoff. |
| III D 0 | refers to the effects of fire on productive response of soils. |
| III G 0,1 | refers to fire-induced changes in the physiognomic and ecological character of the natural vegetation |

B. Sample reference Section II - identified as to location only.

Ferguson, H. (1944) Deterioration of soils and vegetation in Equatoria Province with special reference to grass fires, in: Sudan Govt. Soil Conservation Committee's Report. 138-142. (166)

156 refers to Sudan (formerly Anglo-Egyptian Sudan).

GEOGRAPHICAL CLASSIFICATION

Tropical World General

000 Tropical World General

Africa South of the Sahara General

100 Africa South of the Sahara General

Western Africa

120	West Africa General	136	Upper Volta
121	Liberia	137	Niger
123	Spanish possessions	138	Dahomey
130	Afrique Occidentale Francaise	139	Togo
131	Mauritania	150	British West Africa
132	Senegal	151	Gambia
133	Guinea	152	Sierra Leone
134	Ivory Coast	153	Ghana (Gold Coast)
135	Mali (French Sudan)	154	Nigeria

Central Africa

122	Portuguese possessions: Angola, Guinea, Rio Muni, Cabinda & Islands	141	Gabon
124	Belgian possessions	142	Chad
125	Congo (Leopoldville)	143	Central African Republic (Ubangi- Shari)
126	Rwanda	144	Cameroon
127	Burundi	145	Congo (Brazzaville)
140	Afrique Equatoriale Francaise		

Eastern Africa

160	Northeast Africa General	172	Kenya
161	Somali Republic (Somalia)	173	Tanzania (Tanganyika)
162	Somali Republic (British Somaliland)	174	Uganda
163	French Somaliland	175	Tanzania (Zanzibar & Pemba)
164	Ethiopia	176	Zambia (Northern Rhodesia)
165	Eritrea	177	Rhodesia (Southern Rhodesia)
166	Sudan (Anglo-Egyptian Sudan)	178	Malawi (Nyasaland)
170	East Africa General	179	Mozambique (Port. East Africa)
171	British East Africa possessions		

Southern Africa

- | | | | |
|-----|------------------------------------|-----|--------------------------|
| 180 | Malagasy Republic & Comoro Islands | 191 | Republic of South Africa |
| 181 | Other Western Indian Ocean Islands | 192 | South West Africa |
| 190 | Southern Africa General | 193 | Bechuanaland |
| | | 194 | Basutoland |
| | | 195 | Swaziland |

Latin America

- 200 Latin America General

Middle America

- | | | | |
|-----|------------------------|-----|-----------------------|
| 220 | Middle America General | 225 | Nicaragua |
| 221 | Mexico | 226 | Costa Rica |
| 222 | Guatemala | 227 | Panama and Canal Zone |
| 223 | El Salvador | 228 | British Honduras |
| 224 | Honduras | | |

Insular Caribbean and Bahamas

- | | | | |
|-----|------------------------------------|-----|--|
| 229 | West Indies General | 235 | Trinidad & Tobago |
| 230 | Cuba | 236 | Lesser Antilles |
| 231 | Haiti | 237 | British Caribbean possessions |
| 232 | Dominican Republic | 238 | French and Dutch Caribbean Possessions |
| 233 | Jamaica | 239 | Bahama Islands |
| 234 | Puerto Rico & U. S. Virgin Islands | | |

South America

- | | | | |
|-----|--------------------------|-----|-----------|
| 240 | South America General | 255 | Venezuela |
| 241 | Brazil | 260 | Ecuador |
| 250 | Colombia | 261 | Peru |
| 251 | British Guiana (Guayana) | 262 | Bolivia |
| 252 | Surinam (Dutch Guiana) | 263 | Paraguay |
| 253 | French Guiana | | |

Asia

- | | | | |
|-----|------------------------|-----|---------------------------|
| 300 | Asia General | 335 | Bhutan |
| 320 | Southwest Asia General | 336 | Ceylon |
| 330 | South Asia General | 337 | Maldivé Islands |
| 331 | West Pakistan | 338 | Andaman & Nicobar Islands |
| 332 | Kashmir | 339 | East Pakistan |
| 333 | Nepal | 340 | India |
| 334 | Sikkim | | |

Southeast Asia

- | | | | |
|-----|-------------------------|-----|-----------------------|
| 350 | Mainland Southeast Asia | 357 | Cambodia |
| 351 | Burma | 358 | Malaya |
| 352 | Thailand (Siam) | 359 | Singapore |
| 353 | French Indo-China | 360 | Island Southeast Asia |
| 354 | Laos | 361 | British Borneo |
| 355 | North Viet-Nam | 362 | Sarawak |
| 356 | South Viet-Nam | 363 | Brunei |

Southeast Asia (continued)

364 Sabah (North Borneo)

365 Malaysia

366 Philippines

Indonesia

370 Dutch East Indies

371 Indonesia

372 Sumatra

373 Java & Madura

374 Bali & Lesser Sunda Islands,
Indonesian Timor

375 Kalimantan (Borneo)

376 Sulawesi (Celebes
and other Islands)

377 Portuguese Timor

378 New Guinea (West
Irian, Australian
New Guinea & Papua)

Australia & Oceania

400 Australia & Oceania General

420 Melanesia

430 Micronesia

440 Polynesia

450 Australia

North America

500 North America

Non-Regional

600 Non-Regional

TOPICAL CLASSIFICATION

0. Reference Identification

A. Form number of extracted material

B. Geographic location indicated by content of reference

I. Appraisal of Reference by its Content

0. A general account - reference incidental, mentioned
in passing

1. A narrative account - reference part of general,
broad discussion

2. A detailed narrative account - reference includes
specifics as part of a qualitative analysis

3. Analytical account - reference includes systemati-
cally organized qualitative information derived in
part from field observation

4. Analytical account - reference includes quantita-
tive data and observations derived from field obser-
vation and experimentation

II. Occurrence and Nature of Fire

- A. Incidence and Frequency of Occurrence
 - 0. Year - Date
 - 1. Month - by calendar month or months
 - 2. Season - as indicated by precipitation regime, or vegetative period, or "fire season "
- B. Nature of Fire
 - 0. Cause - natural or cultural
 - 1. Site location
 - 2. Type and speed of movement of fire front; characteristics of flame
 - 3. Characteristics of smoke, e.g., height, density, color, drift
 - 4. Direction and areal pattern of burning
 - 5. Duration and cause of cessation of burning

III. Effects of Fire on the Environment

- A. Topoclimatology
 - 0. Precipitation and humidity regimes (seasonal, diurnal, other)
 - 1. Temperature regimes (seasonal, diurnal, lapse rates, height of inversion)
 - 2. Wind, e.g., local surface winds
 - 3. Visibility (surface, and from the air)
 - 4. Local storms, also fire induced weather
- B. Topography
 - 0. Alteration of rates of erosion
 - 1. Alteration of rates of deposition
 - 2. Distinctive landforms
- C. Hydrography
 - 0. Rates of runoff
 - 1. Surface water flow
 - 2. Flood hazard
 - 3. Pollution
- D. Soils
 - 0. Productive response, e.g., fertility, organic matter, structure, aeration
 - 1. Chemical characteristics, e.g., nutrients, exchange capacities
 - 2. Physical characteristics, e.g., texture, erodability, bulk density
 - 3. Microbiology of solum
- E. Natural Vegetation
 - 0. Physiognomic change due to fire
 - 1. Ecological change
 - 2. Vegetative indicators, e.g., pyrophiles, others
 - 3. Combustibility regions

- F. Cultural Landscape
 - 0. Land uses, e.g., forestry, agriculture, grazing
 - 1. Structures, e.g., buildings, lines of communication, others
 - 2. Settlement patterns, e.g., sedentary, nomadic
- G. Long Term Effects
 - 0. Long term effects on the physical landscape
 - 1. Long term effects on the cultural landscape
- IV. Physical Environmental Influences on the Incidence and Occurrence of Fire
 - A. Regional Climatology
 - 0. Precipitation and humidity, e.g., precipitation regimes, orographic effects, effective precipitation, mist, fog, drought
 - 1. Temperature, e.g., annual and diurnal march, range, variability, lapse rates, inversions
 - 2. Weather, e.g., prevailing winds, fronts, storms
 - 3. Air masses, e.g., frequency of occurrence, duration and characteristics
 - 4. Seasons, e.g., criteria, indices, and formulae used to define seasons
 - B. Topoclimatology
 - 0. Local winds, e.g., land and sea breezes, upslope and katabatic winds, shelter belt effects
 - 1. Local storms
 - 2. Other local climatic phenomena
 - C. Surface Configuration
 - 0. Relief features, local relief
 - 1. Surface materials, e.g., rock outcrops, sterile surface materials, laterite layers, others
 - 2. Hydrographic and hydrologic factors, e.g., surface drainage as barriers, flood hazard, runoff, characteristics of ground water table
 - 3. Edaphic factors, e.g., soil types and characteristics, soil-water relationships
 - D. Natural Vegetation
 - 0. General physiognomic character noting a few dominant species
 - 1. Broad classification of vegetation with geographic distribution
 - 2. Vegetation types, including site location, dominant and subdominant species
 - 3. Seasonal change in vegetation affecting combustibility
 - a) climatic factors, e.g., moisture regimes
 - b) vegetative factors, e.g., pyrophiles
 - c) cultural factors, e.g., lack of fuel to sustain fire due to man's activity

V. Cultural Environmental Influences on Incidence and Occurrence of Fire

- A. Peoples and Population
 - 0. Numbers, density, man-land ratios
 - 1. Ethnic and racial factors, e.g., cultural history and economic history
 - 2. Religious and political factors, e.g., tribal taboos and religious practices associated with fire, tribal organization
 - 3. Settlement pattern and ways of life, e.g., nomadic, sedentary, shifting cultivation
- B. Technology of Use of Fire
 - 0. Preparation for burning, e.g., site location, supply of fuels, fire control
 - 1. Techniques of firing
 - 2. Seasonal or cyclical patterns of economic use of fire, e.g., land clearing, grassland management, forestry
 - 3. Seasonal or cyclical patterns of biotic use of fire, e.g., gathering, hunting
 - 4. Repeated patterns of fire use, e.g., disease or insect control, warfare or raiding, pyromania
- C. Distribution of Cultural Practices of Fire Use
 - 0. Seasonal, monthly, or planting and harvesting patterns
 - 1. Types and kinds of burning regions identified by cultural criteria

SECTION I

Tropical World General

- Allouard, P. (1951) La lutte contre les incendies de forêts dans les pays tropicaux, Rev. Int. Bois., 18, No. 161:13-16. (000, 357: I 1; II B 0; V B 1.)
- Anonymous, (1948) Shifting cultivation, The Tropical Agriculturist, 104:1-2. (000: I 1; V A 3.)
- Aubert de la Rue, E. (1958) Man's influence on tropical vegetation, Ninth Pacific Science Congress, Proc., Bangkok, 20:81-94. (000: I 1; III D 0; III E 0; III G 0; V A 0; V B 0.)
- Baldanzi, G. (1960) Burning and soil fertility, Inter. Congress Soil Sci., Trans. 7, No. 2:523-530. (000: I 2; III D 0.)

- Bartlett, H. H. (1959) A bibliographic review of the literature on shifting agriculture and fire as ecological agencies in the tropics. Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association, 1957, pp. 78-80. (000: I 2; III G 0,1.)
- Bartlett, H. H. (1956) Fire, primitive agriculture and grazing in the tropics, in: Thomas, William Jr. (ed.) Man's role in changing the face of the earth, University of Chicago Press, Chicago, pp. 692-720. (000: I 3; II B 0; III E 0,1; III G 0,1; IV C 0,1,2,3; IV D 1; V A 0 2,3; V B 0,1,2; V C 0,1.)
- Beard, J. S. (1944) Climax vegetation in tropical America, Ecology, 21. No. 2:127-258. (000: I 4; IV D 2.)
- Budowski, Gerardo (1964) Some thoughts on vegetation classification on a worldwide basis. Forestry Program. Inter-American Institute of Agricultural Sciences of the OAS. Training and Research Center. Turrialba, Costa Rica. 4 pp. (000: I 2; IV D 0; IV D 3b.)
- Budowski, Gerardo (1956) Tropical savannas, a sequence of forest felling and repeated burnings, Turrialba. 6, No. 1-2:23-33. reprint: Mus. de Cien. Nat., B. 6/7(1/4):63-87. (1960) (000: I 4; III A 0; III B 0; IV A 3; IV C 2,3; IV D 0; IV D 3b; V B 0.)
- Budowski, Gerardo (1961) Which is the forest influence upon the climate. Instituto Interamericano de Ciencias Agrícolas, Turrialba, Costa Rica. (000: I 2; III A 0.)
- Burtt-Davy, (1938) The classification of tropical woody vegetation types, Imp. for. Inst. (Oxford). Paper No. 13. (000: I 4; IV D 1.)
- Chevalier, A. (1948) Les cartes de végétation naturelle et les cartes agricoles de territoires cultivés ou subissant l'action de l'homme. Rev. Int. de Bot. Appl. et d'Agron. Tropicale, 27. No. 309-310:328-334. (000: I 3; III G 0; IV D 2.)
- Conklin, Harold C. (1954) An ethnoecological approach to shifting agriculture. N. Y. Acad. Sci., Trans. ser. 2, No. 17:133-142. (000: I 3; V B 2.)
- Dessens, Henri and Jean (1962) Les plus anciennes descriptions de nuages et de pluies consécutifs à des incendies. Puy de Dôme, Observatoire Bull. 1962: 103-105. (000: I 2; III A 4.)

- Devred, R. (1951) Une legumineuse comme essence de coupe-feu le Sweetia brachystachia BTH. Première Conf. Forestière In'erafricaine, dec. 4-12, 1951, pp.481-492. (000: I 3; II A 2; V B 1.)
- Fickender, Ernst (1950) Tierra calcinada en tropicos, Instituto de Estudios Africanos, Consejo Superior de Investigaciones Cientificas, Madrid. 16 pp. (000: I 1; III D 0; III E 0; IV A 0; IV C 3.)
- Fosberg, F. R., B. J. Garnier and A. W. Kuehler (1961) Delimitation of the humid tropics, Geog. Rev., 50, No. 3:333-347. (000: I 2; IV A 0; IV D 0.)
- Gourou, Pierre (1947) Les pays tropicaux: principes d'une géographie humaine et économique, Presses Universitaires de France, Paris, 196 pp. (000: I 3; III B 0; III G 1; IV D 3b; V A 3; V B 2.)
- Gourou, Pierre (1956) The quality of land use of tropical cultivators, in: Thomas, W.L. (ed), Man's role in changing the face of the earth, Chicago, U. of Chicago Press, pp. 336-349. (000: I 3; III E 0; V A 3; V B 0; V C 0,1.)
- Gourou, Pierre (1961) Trans.:E.D. Laborde, The tropical world, its social and economic conditions and its future status, Longmans, Green and Co., London. New York, Toronto, 159 pp. (000: I 3; II A 0,2; II B 4; III D 0,1,2; III E 1; III G 0; IV A 0,4; IV C 3; IV D 0,1; V A 0,2,3; V B 0,1,2,3; V C 0,1.)
- Haden-Guest, Stephen, John Wright, and Eileen Teclaff (1956) A world geography of forest resources, Ronald Press, New York, 736 pp. (000: I 2; III B 0; IV A 0; IV D 3b.)
- Haig, I. T., et al. (1958) Tropical silviculture. (3 vols.) FAO Forestry and Forest Products Studies No. 13, Food and Agriculture Organization, Rome, Vol. I-190 pp., Vol. II 413 pp., Vol. III 101 pp. (000: I 3; IV D 0; IV D 1,2.)
- Humbert, H. (1953) Le problème du recours aux feux courants, Rev. Inter. de Bot. Appl. et d'Agron. Tropicale, 33:19-28. (000: I 2; III B 0; III G 0.)
- Humbert, H. (1952) Le problème du recours aux feux courants, IFAN, Dakar, 11 pp. (000: I 2; III E 0,1.)
- Joubert, A. (1933) L'action des civilisations primitives sur la composition des formations forestières. Congress Association Française pour l'Avancement des Sciences, Comptes Rend. de la 57-e Session, pp. 492-497. (000: I 3; IV D 3; V B 2.)
- Kellogg, Charles E. (1963) Shifting cultivation, Soil Sci., 95:221-230. (000: I 2; V B 1.)

- Leach, E. R. (1959) Some economic advantages of shifting cultivation, Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association, 1957, 7: 64-65. (000: I 1; V A 0.1; V B 3.)
- Muschett, W. R. (1955) The merits of burning trash prior to replanting, J.A.S.T. Journal, 18:1-3. (000: I 3; V B 2.)
- Newton, K. (1960) Shifting cultivation and crop rotations in the tropics, Papua and New Guinea Agricultural Journal, 13, No. 3:81-118. (000,152: I 2; III F 0; III G 0; V B 2; V C 0.)
- Nyyssönen, Aarne (1962) Aerial photographs of tropical forests, Unasylva, 16, No. 1:3-12. (000: I 2; IV D 2)
- Phillips, W. S. (1962) Fire and vegetation of arid lands, Tall Timbers Fire Ecol. Conf., Proc. First Annual, 81-93 (000: I 2; II A 1; III G 0.)
- Poore, M. E. D. (1963) Problems in the classification of tropical rain forest. J. of Trop. Geog., 17:12-19 (000: I 4; IV D 0.)
- Popenoe, Hugh (1963) The pre-industrial cultivator in the tropics, Proceedings and papers of the IUCN 9th Technical Meeting, Nairobi, Kenya, Sept. 1963. Part I: Pre-industrial man in the tropical environment, IUCN Publications new series No. 4. 1964. pp. 66-73. (000 I 3; III D 0; III G 1; V A 3.)
- Portig, W. H. & J. R. Berhardt. (ed.) (1962) Conference on Tropical Meteorology, Asbury Park, N.J., May 10-11. Summary Proceedings 50 pp. (000: I 2; IV A 0,1,2,3; IV B 0,1,2.)
- Richards, P. W. (1965) Personal communication. (000: I 2; II A 2; II B 5; III D 0, IV B 2.)
- Richards, P. W. (1961) The types of vegetation of the humid tropics in relation to the soil, Tropical Soils and Vegetation, UNESCO Abidjan Symposium:15-24. (000: I 3; IV C 3; IV D 1.)
- Richards, P. W. (1952) The tropical rain forest: an ecological study. Cambridge, The University Press. 450 pp. (000: I 4; IV D 0,1,2.)
- Saldarriaga, M. (1956) Y las quemaz? Agr. Trop., 12:669-673 (000: I 1; III E 0; III G 0,1.)
- Shantz, H. L. (1947) The use of fire as a tool in the management of the brush ranges of California, California Division of Forestry. 156 pp. (000. 500: I 3; II A 2; II B 0; III A 0,1,2,3; III C 0,1; III D 0,1,2,3; III E C.1,3; III G 0,1; IV A 0; IV B 0; IV D 0; V B 1; V C 0, 1.)

- Tempany, Harold A. (1951) Imperata grass: a major menace in the wet tropics, World Crops, 3:143-146. (000: I 1; III G 0.)
- Tempany, Harold (1950) Shifting cultivation in tropical regions, Br. Agric. Bull., 3:112-114. (000: I 1; II A 2; V B 1,2.)
- Thomas, William L., Jr. (ed.) (1956) Man's role in changing the face of the earth, University of Chicago Press, Chicago, Ill., 1193 pp. (000: I 3; III G 0,1; V A 0,1; V B 0,1; V C 0,1.)
- United Nations Food and Agriculture Organization (1957) Shifting cultivation, Tropical Agriculture, 34, No. 3: 159-164. (000: I 1; II B 0.)
- United Nations Food and Agriculture Organization (1959) Shifting cultivation -- FAO's position and course of action, Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association 1957, 7:71. (000: I 0; V B 1.)
- van Steenis, C. G. G. J. (1958) Rejuvenation as a factor for judging the status of vegetation type: the biological nomad theory, Study of Trop. Veg., UNESCO, pp. 216-218. (000: I 2; IV D 3b.)
- Watters, R. F. (1964) Some problems of shifting cultivation, (Seminar, Jan. 6, 1964), Tropical Center for Research and Graduate Training, Turrialba, Costa Rica. (000: I 1; IV C 2; V A 0.)
- Watters, R. F. (1960) The nature of shifting cultivation: a review of recent research, Pacific Viewpoint, 1, No. 1:59-99. (000: I 2; III D 0,1,2,3; III E 0,1,2; III F 2; III G 0; IV A 0; IV C 3; IV D 3; V A 0,3; V B 0,1,2; V C 0.)
- Whyte, C. R. (1962) The myth of tropical grassland, Tropical Agriculture, 39:1-11. (000: I 1; IV D 0.)
- Whyte, R. O. & T. R. G. Moire, and J. P. Cooper, (1959) Grasses in agriculture, FAO Agricultural Studies, No. 42. Plant Production and Protection Division, 416 pp. (000: I 4; IV A 0; IV D 0.)

Africa South of the Sahara General

- Adlard, P. G. (1961) The background to a burning policy, Dept. of Forestry and Game, Southern Rhodesia. Reprint: source unknown, 11 pp. (100: I 3; II A 1; III D 0; III E 0,1; III G 0,1; IV B 0; V C 1.)

- Aubréville, A. (1949) Climats, forêts et désertification de l'Afrique tropicale. Soc. d'Edit. Géograph., Marit. et Colon., Paris, 352 pp. (100: I 3; III B 0; III G 0; IV D 3b)
- Aubréville, A. (1955) La typologie topographique forestière. Bois. et For. de Trop., 41:3-7. (100: I 3; IV D 0.)
- Aubréville, A. (1961) Nomenclature des formations forestières africaines. Deuxième Conf. Forest. Interafr., C.S.A., Publ. # 43, 2:621-629. (100: I 3; IV D 0.)
- Aubréville, A. M. (1947) The disappearance of tropical forests of Africa, Unasylva, 1, No. 1:5-11 (100: 130: I 3; II B 0; III B 0; III E 0,1,3; III G 0; IV A 0; IV B 0; IV C 2; IV D 0; V A 0,3; V B 2.)
- Bagnouls, F. and H. Gaussen (1953) Période de sécheresse et végétation. C.R. Ac. Sci., 236, No. 10:1075-1077. (100: I 4; IV A 0.)
- Borden, B. N. (1964) Studies on Andropogon gayanus, III: an outline of its biology, Jour. of Ecol., 52:255-271. (100: I 3; II A 2; II B 0; III E 0,1,3)
- Borden, Bernard N. (1964) The dry seasons of inter-tropical Africa and Madagascar, The Jour. of Tropical Geog., 19: 1-3. (100: I 4; II A 1; IV A 0.)
- Brauner, Walter (1908) Die periodische Grasbrände im tropischen Afrika, ihr Einfluss auf die Vegetation und ihre Bedeutung für die Landeskultur, Mitteilungen aus den Deutschen Schutzgebieten, 20. 2 Heft:113-139. (100: I 2; IV D 0; V B 0,1,2.)
- Camden, V. W. Lovett (1877) Across Africa, Harper and Brothers, New York, 508 pp. (100: I 1; II B 0,2; III B 0; V C 1.)
- Chevalier, A. (1909) L'extension et la régression de la forêt vierge de l'Afrique tropicale. C.R. Ac. Sci., 149: 458-461. (100: I 1; IV D 0.)
- Chevalier, A. (1933) Le territoire géobotanique de l'Afrique tropicale nord-occidentale et ses subdivisions. Bull. Soc. Bot. Fr., 80:4-26. (100: I 1; IV D 1.)
- Chevalier, A. (1928) Sur la dégradation des sols tropicaux causée par les feux de brousse et sur les formations végétales régressives qui en sont la conséquence, C. R. Ac. Sci., Paris, 188, No. 1:84-86. (100, 241: I 2; IV D 3b)
- Chevalier, A. (1928) Sur l'origine des campos brésiliens et sur le rôle des Imperata dans la substitution des savanes aux forêts tropicales. C. R. Ac. Sci., Paris, 187, No. 22:997-999. (100: 241: I 2; IV D 3b.)

- Commission de Coopération Technique en Afrique au Sud du Sahara (1951) Première Conférence Forestière Inter-africaine. Commission de Coopération Technique en Afrique au Sud du Sahara, Abidjan, 562 pp. (100: I 1; III G 1,2; V B 1.)
- Commission for Technical Cooperation in Africa South of the Sahara (1953) Proceedings of the Third International Conference for the Protection of the Fauna and Flora of Africa, Bukavu, Belgian Congo 1953, n.p. (100: I 2; V B 1,2.)
- Cufondontis, G. (1955) Kritisches Referat über die Bedeutung der Termiten für das Verständnis der afrikanischen Savannen-Vegetation, Österreichische Botanische Zeitschrift, Band 102:501-519. (100: I 2; IV D 0.)
- C. W. Thornthwaite Associates (1962) Average climatic water balance data of the continents, Part I: Africa, Publications in Climatology, 15, No. 2:115-287, Laboratory of Climatology, Centerton, New Jersey. (100: I 4; IV A 0,1.)
- Academy of Sciences, Division of Anthropology and Psychology, (1961) Human environments in Middle Africa, National Research Council, Washington, D.C. 132 pp. (100: I 3; II B 0; IV C 3; V A 0; V A 3.)
- Dundas, J. (1944) Bush burning in tropical Africa, Empire Forestry Jour., 23:122-125. (100: I 1; V B 1.)
- Duvigneaud, P. (1955) Études écologiques de la végétation en Afrique tropicale, Travaux du Laboratoire de Botanique Systematique et de Phytogéogr. de l'Univ. Libre de Bruxelles, Publ. 19. (Reprint from Annales Biol. 51, fasc. 5-6:131-148. 1955). (100: I 4; IV D 2.)
- Griffith, A. L. (1961) Dry woodlands in Africa south of the Sahara, Unasylva, 15, No. 1:10-21. (100: I 2; IV A 0,1; IV C 0; IV D 0.)
- Falkner, Franz (1939) Beiträge zur Agrargeographie der afrikanischen Trockengebiete, (Inaugural-Dissertation) A. Gelschlager's Buchdruckerei, Basel, 76 pp. (100: I 2; IV A 3.)
- Fisher, W. Singleton (1948) Burning the bush for the game, African Studies, 7:36-38. (100: I 2; II B 0,1,3; III A 0; IV B 0,2; V A 3.)
- Guilloteau, J. (1957) The problem of bush fires and burns in land development and soil conservation in Africa south of Sahara, Sols Africains, 4, No. 2:64-102. (100: I 3; II A 2; II B 2; III D 0,1,2; III E 1,2,3; III F 0; III G 0,1; IV D 0,1,3b; V B 1,2.)

- Hailey, Lord (1945) An African survey: a study of problems arising in Africa south of the Sahara, Oxford University Press, London, New York, Toronto. 1838 pp (revised 1956). (100: I 3; III B 0; IV C 2; IV D 1.3b; V A 3; V B 0.1.3)
- Harroy, Jean-Paul (1949) Afrique: terre qui meurt. La dégradation des sols africains sous l'influence de la colonisation, Marcel Hayez. Bruxelles, 557 pp. (100: I 1; II B 0.3; III B 0; III G 0.1; IV D 1.)
- Jones, William O. (1959) Manioc in Africa, Stanford University Press, Stanford, Calif., 315 pp. (100: I 2; III B 0; III G 0.1.)
- Keay, R. W. J. (1956) African vegetation meeting at Yangambi, Nature, (London). 178. No 4545:1273-1274. (100: I 1; III G 0.)
- Kimble, George H. T (1960) Tropical Africa, Vol. 1. Land and livelihood. Twentieth Century Fund, New York. 603 pp (100: I 1; II A 2; III ? 0; III B 0; III F 0; III G 0; IV D 3b; V A 3; V B 0.1.2)
- Laudelout, H. (1954) Étude sur l'apport d'éléments minéraux résultant de l'incinération de la jachère forestière. Inter-African Soil Conf., Proc. 2:383-388 (100: I 3; III D 1.)
- Lauer, W (1952) Humide und aride Jahreszeiten in Afrika und Südamerika und ihre Beziehung zu den Vegetationsgürteln. Bonner Geogr. Abhandlungen. 9:15-98 (100. 240: I 4; IV A 0.1.4.)
- Michelmores, A. P. (1939) Observations on tropical African grassland. J. of Ecol. 27:282-312 (100: I 3; III E 1; IV A 0.1; IV D 3)
- Monod, T. (1963) Après Yangambi: notes de phytogéographie africaine, Bull IFAN. Sér. A. Sci nat. 25. No. 2: 594-655. (100: I 3; IV D 0.1)
- Murdock, George P. (1959) Africa, its peoples and their culture history. McGraw-Hill, New York, Toronto, London. 456 pp (100: I 3; V A 1.)
- Nash, C. A. M (1960) Fire control in savanna forest reserves. Forest Research Conference. Federal Government Printer, Lagos, Jan. 1960:11-16. (100: I 2; III E 3; IV D 3b; V B 1.)
- Nye, P. H. and D. J. Greenland (1960) The soil under shifting cultivation, Technical Comm No. 51 of Commonwealth Bur. of Soils, Comm Agr Bur., Harpenden, 140 pp. (100: I 3; III D 0.1.2.3; IV C 3; V A 3; V B 0.1.2.3.)
- Phillips, John (1959) Agriculture and ecology in Africa, Faber & Faber, London. 412 pp (100: I 2; III D 0.1; III E 0.1; III F 0; III G 0.1; IV D 1; V A 3.)

- Rattray, J. M. (1960) The grass cover of Africa. FAO. Agricultural Studies No. 49. Rome, 168 pp. (100: I 4; III D 0,2.)
- Scientific Council for Africa South of the Sahara (1956) Phytogeography, CSA Specialist meeting on phyto-geography, Yangambi, July 28-Aug. 8, 1956, 33 pp. (100: I 4; IV D 1.)
- Shantz, H. L. (1940) Agricultural regions of Africa, Part I; Basic factors, Economic Geog., 16, No. 1: 1-47, 122-161, 341-389. (100: I 2; III B 0; V A 3.)
- Shantz, H. L. (1948) Estimation de la régression des forêts de l'Afrique tropicale, Unasylva, 2, No. 2. n.p. (100: I 1; III G 0)
- Shantz, H. L. and B. L. Turner (1958) Photographic documentation of vegetational changes in Africa over a third of a century, Report No. 169, College of Agriculture, University of Arizona, 158 pp. (100: I 2; III G 0.)
- Skaife, S. H. (1948) Our continent's scorched earth policy; life in all parts of Africa threatened by senseless burning of vegetation, Farmer's Weekly. (Bloemfontein) 76:52-53, 55. (100: I 1; III G 0,1; IV D 2.)
- Stebbing, E. P. (ed.) (1942) Commission of Research: Africa (and other tropical countries), Commission set up to study deforestation and erosion in tropical countries under the auspices of the Royal African Society, mimeogr., n.p. (100: I 2; III B 0; III F 0; III G 0,1.)
- Thomas, A. S. (1959) Grass and fire. Eighth International Grasslands Congress, 1:405-407. (100: I 2; III B 0; III G 0; IV A 2.)
- Trewartha, G. T. and W. Zelinsky (1954) Population patterns in tropical Africa, Annals, A.A.G., 44:135-162. (100: I 1; V A 0,1.)
- Trochain, Jean L. (1957) Accord interafricain sur la définition des types de végétation de l'Afrique tropicale, Bull. Inst. d'Etudes Centrafricaines, nouvelle série, 13, 14:55-93. (100: I 4; IV D 1.)
- Trochain, Jean (1951) Nomenclature et classification des types de végétation en Afrique noire française (Deuxième note), Bull. Inst. d'Etudes Centrafricaines, nouvelle série, 2:9-18. (100: I 4; IV D 1.)
- Troll, C. (1963) Landscape ecology and land development with special reference to the tropics, Jour. of Trop. Geog., 17:1-11. (100: I 3; IV A 3; IV D 1,3b.)
- UNESCO (1963) A review of the natural resources of the African continent, UNESCO International Documents Service, Columbia Univ. Press, New York, 437 pp. (100: I 1; IV A 0,1; IV C 0.1.)

- Urgunart, D. H. (1955) Cocoa. Longmans. Green and Co., London, 230 pp. (100: I 1; III G 0.1; V A 3.)
- Walter, Heinrich (1958) Klimadiagramm-Karte von Afrika. Ludwig Rohrscheid Verlag. Bonn, 27 pp. (100: I 3; IV A C,1,2,3,4)
- Wernstedt Frederick L. (n.d.) World climatic data, Africa, Dept. of Geography. Pennsylvania State University, 101 pp (100: I 4; IV A 0.1.)
- Worthington, E. B. (n.d.) Science in the development of Africa. Prepared at the request of the Commission for Technical Cooperation in Africa South of the Sahara, and Scientific Council for Africa South of the Sahara. Stephen Austin and Sons, Great Britain. 462 pp. (100: I 3; II A 0; III D 2; III E 0; V A 3; V B 0.1, 3; V C 1.)

Western Africa

- Adam, J. G. (1957) Contribution à l'étude floristique des pâturages du Sénégal, L'Agronomie Tropicale, 12, No. 1:67-113 (132: I 3; IV A 0.1; IV C 0.2,3; IV D 2.)
- Adam, J. G. (1961) Contribution to the study of the flora and vegetation of West Africa. the lower Casamance (Senegal). (in French). Bull. Inst. Fr. d'Afr. Noire, Sér. A.. Sci. Nat.. 23. No. 4:911-993. (132: I 4; IV C 3; IV D 2.)
- Adam, J. G. (1948) Les reliques boisées et les essences des savanes dans la zone préforestière en Guinée française, Bull. Soc. Bot. Fr. 95:22-26. (133: I 3; III E 0.1; III G 0; IV D 2.)
- Adam, J. G. (1959) La Flore des calcaires de Rufisque-Bargny, Bull. IFAN, Sér. A., Sci. Nat.. 21, No. 4: 1160-1176. (132: I 4; IV D 2.)
- Adam, M. J. (1956) Contribution à l'étude floristique des pâturages du sahel zone sylvo-pastorale au sahel sénégalais (Djoloff et Fouta-Toro-Vallée du Sénégal exclue), Section des Recherches de l'Inspection Générale des Eaux et Forêts de l'A.O.F., Dakar. 59 pp. (132: I 4; IV D 0.)
- Adjanooun, E. J. (1962) Etude phytosociologique des savanes de basse Côte d'Ivoire (savanes lagunaires), Vegetatio. 11:1-38 (134: I 2; III B 0.)

- Ahn, Peter M. (1961) Soils of the lower Tano Basin, south-western Ghana. Government Printer, Accra. 266 pp. (153: I 3; IV D 1.)
- Ahn, Peter M. (1961) Soil-vegetation relationships in the western forest areas of Ghana, Tropical Soils and Vegetation: UNESCO Abidjan Symposium 1959, pp. 75-84. (153: I 3; IV A 0; IV C 3; IV D 1.)
- Ahn, Peter (1960) The mapping, classification and interpretation of Ghana forest soils for forestry purposes, Fifth World Forestry Cong. 1960, Proc., pp. 508-516. (153: I 4; II C 3; III E 3; IV A 0; IV C 1,3; IV D 1.)
- Ainslie, J. R. (1926) The physiography of Southern Nigeria and its effect on the forest flora of the country, Oxford Forestry Memoirs, No. 5, Clarendon Press, Oxford. 36 pp. (154: I 3; III E 3; IV D 0,3b; V A 3; V B 2.)
- Alexander, Boyd (1908) From the Niger, by Lake Chad, to the Nile, Jour. Manchester Geog. Soc., 24:145-162. (130: I 2; IV D 2; V A 3.)
- Anonymous (1957) Fire control plots in savanna forest, Rep. For. Res. Nigeria 1954/1955, pp. 8-9. (154: I 4; III D 2; III G 0.)
- Anonymous (1951) Natural regeneration of savanna woodland in Nigeria as affected by fire, Rep. For. Adm. Nigeria 1949/1950. pp. 17-20. (154: I 3; III E 0,1.)
- Aubréville André (1950) Flore forestière soudano-guinéenne, A.O.F. - Cameroun- A.E.F., Société d'Éditions Géographiques, Maritimes et Coloniales, 523 pp. Paris. (130, 140, 144: I 2; III B 0; IV A 0; IV D 0,3b.)
- Aubréville, A. (1959) Les fourrés alignés et les savanes à termitières buissonnantes des plaines de Winneba et d'Accra, Bois et For. d.Trop., 67:21-24. (153: I 3; III B 0; IV A 2.)
- Bergeroo-Campagne, M. B. (1956) L'agriculture nomade, Vol. I, Collection F.A.O., Nations Unies Pour l'Alimentation et l'Agriculture, 230 pp. (154: I 3; II A 2; II B 1; IV C 3; IV D 0,3b; V A 2,3; V B 0,2,3.)
- Biobaku, Saburi O. et al. (1949) Ibadan, The University College, Ibadan, 53 pp. (154: I 2; V B 2.)
- Bohannan, Paul (1954) Tiv farm and settlement, (Colonial Research Studies No. 15), Her Majesty's Office, London, 87 pp. (154: I 3; II A 2; IV D 3b; V F 2.)
- Boughey, A. S. (1965) Personal Communication. (150, 177: I 3; II B 4; III D 0,2.)

- Buchanan, K. M. and J. C. Pugh (1955) Land and people in Nigeria, University of London Press, London, 252 pp. (154: I 1; IV A 0,1; IV C 0; IV D 0; V A 0,1,3)
- Buchanan, Keith (1955) The Northern Region of Nigeria: the background of its political duality, Geog. Rev., 43:451-473. (154: I 3; II A 2; IV D 1; V B 2.)
- Busse, Walter (1907) Das südliche Togo. In: Kuusten, G. and H. Schenck, Vegetationsbilder Vierte Reihe, Gustav Fischer, Jena, Heft 2, Taf. 7-12 (139: I 2; II A 2; IV D 3b; V B 2.)
- Buxton, P. A. (1935) Seasonal changes in vegetation in the north of Nigeria. Jour. of Ecol., 23:134-139. (154: I 3; IV A 0,1; IV D 3)
- Cardinall, Allan Wolsey (1932) The Gold Coast, 1931. ... based on figures and facts collected by the Chief Census Officer of 1931. The Government Printer, Accra, 255 pp (153: I 3; II A 0; III G 0,1; V A 3.)
- Charter, J. R. and R. W. J. Keay (1960) Assessment of the Olokemeji fire-control experiment (investig. 245) 28 years after institution, Niger. For. Inform. Bull., No. 3, 32 pp. (154: I 4; III E 0,1; III G 0.)
- Cnevalier, A. (1950) La progression de l'aridité, du dessèchement et de l'ensablement et la décadence des sols en Afrique occidentale française. C. R. Ac. Sci., 230, No. 18:1550-1553 (130: I 2; III G 0,1; IV A 0,1; IV C 3.)
- Chipp, T. F. (1927) The Gold Coast forest: a study in synecology, Oxford Forestry Mem. No. 8, Oxford Clarendon Press, Oxford, 94 pp. (150: I 3; IV D 1,3; V A 0.)
- Church, R. J. Harrison (1957) West Africa, a study of the environment and man's use of it, Longmans, Green and Co., London and New York, 547 pp. (130: I 2; IV D 0; V B 1.)
- Clayton, W. D. (1960) Derived savanna in Kabba Province, Nigeria. Jour. of Ecol., 49:595-604. (154: I 3; III G 1; IV A 0,1; IV C 3; IV D 0)
- Clayton, W. D. (1958) Secondary vegetation and the transition to savanna near Ibadan, Nigeria, Jour. of Ecol., 46:217-238 (154: I 3; III D 0,2; III E 0,1.)
- Cunningham, R. K. (1963) The effect of clearing a tropical forest, Jour. of Soil Sci., 14:334-345. (153: I 3; III D 0,1,2.)

- Devred, R. (1957) Limite phytogéographique occidente-méridionale de la région guinéenne au Kwango, Bull. Jard Bot de l'Etat, 27. No 3:417-431. (133: I 3; IV D 2.)
- Dougall, W. H. (1948) Native agricultural practices - bush burning. Annual Report of the Department of Agriculture for 1948, pp. 33-35 Government Printer, Freetown, Sierra Leone (152: I 3; III D 0.)
- Duchaufour, P. (1952) La dégradation des sols forestiers en Cote-d'Ivoire, Révue forestière française, décembre 1952 (134: I 2; III D 0.1,2)
- Dueng, H. T. (1946) Les incendies de brousse et les adaptations de la végétation du bassin inondé du Moyen Niger. Rev Inter de Bot. Appl et d'Agron Tropicale, 26:306-309. (130: I 1; III B 0; V C 1.)
- Dundas, J. (1944) The burning question. Farm and Forest, 5 No 2:8-10. (154: I 1; III G 0; V B 1.)
- Dundas, J. (1938) Vegetation types of the Colonie du Niger, Imp For. Inst. Paper No 15, 10 pp (137: I 4; IV D 2)
- Fairbairn, W. A. (1939) Ecological succession due to biotic factors in northern Kano and Katsina Provinces in northern Nigeria. Imp. For. Inst. Paper No. 22. (154: I 3; III G 0.1; IV D 0)
- Faulkner, O. T. and J. R. Mackie (1933) West African agriculture. University Press, Cambridge, 168 pp. (154: I 3; II A 1; IV C 3; V A 3; V B 2.)
- Forde, C. Daryll (1937) Land and labor in a Cross River village southern Nigeria. Geog Jour 90:24-49. (154: I 1; V A 3)
- Forde, C. Daryll (1951) The Yoruba-speaking peoples of south-western Nigeria. Ethnographic Survey of Africa Part IV, International African Institute, London. 102 pp (138, 154: I 3; II A 2; IV D 1)
- Forbes, M. R. W. Steel and P. Ady (1947) Ashanti survey 1945-56: an experiment in social research, Geog Jour, 110:149-179 (153: I 3; II A 2; IV A 3; IV D 1.)
- Gamble, David P. (1957) The Wolof of Senegambia, Ethnographic Survey of Africa. Western Africa. Part XIV, International African Institute, London. 105 pp (132: I 3; V B 2)

- Garnier, B. J. (1957) Potential evapotranspiration and its use in agricultural development, in: West African Cotton Research Conference, Nov. 18-23, 1957, Nigeria, Ministry of Agriculture, Appendix xxx. n.p. (154: I 4; IV A 0, 1, 4; IV C 2)
- Ghana (1958) Annual Report Forestry Department (1958). Government Printer, Accra, 55 pp. (153: I 2; III G 0; IV D 1; V A 2, 3.)
- Ghana (1958) Report of Department of Soil and Land Use Survey for Jan. - July, 1957, Government Printer, Accra, n.p. (153: I 4; IV C 3; IV D 1.)
- Ghana (1958) Report of the Department of Soil and Land Use Survey for 1956, Government Printer, Accra, n.p. (153: I 4; IV D 1.)
- Ghana (1957) Report of the Department of Soil and Land Use Survey, June 1951 - Dec. 1955, Government Printer, Accra, n.p. (153: I 4; IV D 1.)
- Giffard, P. L. (1965) Personal communication. (132: I 2; V B 1.)
- Grosmaire, P. (1957) Eléments de politique sylvo-pastorale au Sahel sénégalais. Part I: Les feux de brousse. Part II: Les conditions du milieu. Service Forestière. St. Louis, Sénégal, n.p. (132: I 3; II A 2; II B 0; III D 0; III E 0; IV A 0, 1, 2; V A 3; V B 1, 2.)
- Grove, A. T. (1949) Farming systems and erosion on some sandy soils in southeastern Nigeria. Bull. Agric. Congo Belge, 40, No. 3-4:2150-2155. (154: I 2; III D 2; V A 3.)
- Guernier, Eugène (ed.) (1951) Cameroun, Togo. Encyclopédie de l'Afrique française (Encyclopédie coloniale et maritime), Editions de l'Union française, Paris, 572 pp. (139, 44: I 2; IV A 0, 1; IV D 0, 2; V A 0, 1, 3)
- Hamblen, D. J. (1964) The vegetation of granitic outcrops in western Nigeria, Jour. of Ecol., 52:573-594. (154: I 4; III D 0; IV D 2.)
- Holsoe, Torkel (1964) Personal communication. (121: I 2; III E 0, 1; III G 0.)
- Hopkins, Brian (1962) A trend towards a longer dry season in southwestern Nigeria, Nature, (London), 194:861-862. (154: I 3; IV A 0; IV B 2.)
- Hopkins, Brian (1962) Vegetation of the Olokemeji Forest Reserve, Nigeria, Part I: General features of the Reserve and the research sites, Jour. of Ecol., 50: 559-614. (154: I 4; IV D 2.)

- Hopkins, Brian (1965) Vegetation of the Olokemeji Forest Reserve, Part II: The climate, with special reference to its seasonal changes, Jour. of Ecol., 53, No. 1: 109-124. (154: I 4; IV A 0,1,2,3.)
- Hopkins, Brian (1965) Vegetation of the Olokemeji Forest Reserve, Part III: The microclimates, with special reference to their seasonal changes, Jour. of Ecol., 53, No. 1:125-138. (154: I 4; IV A 0,1; IV B 2.)
- Irvine, F. R. (1954) A note on the use of plant ashes in native agriculture in W. Africa, World Crops, 6:71-72. (120: I 1; V A 3.)
- Jaeger, P. and D. Winkoun (1962) Premier contact avec la flore et la végétation du plateau de Bandiagara, Bull. IFAN, Sér. A., Sci. Nat., 24, No. 1:69-111. (130: I 3; IV A 0,1; IV C 0,3; IV D 2.)
- Jones, Brynmor (1938) Desiccation and the West African colonies, Geog. Jour., 91:401-423. (120: I 1; III G 0.)
- Jones, E. W. (1963) The forest outliers in the Guinea zone of northern Nigeria, Jour. of Ecol., 51, No. 2:415-434. (154: I 3; II B 0; IV D 1,3b.)
- Jouvanceau, J. (1961) Les travaux de protection totale contre les feux dans les forêts classées de la région de Segou, Centre Technique Forestier Tropical, Nogent-sur-Marne, 18 pp. Also in: Bois et For. d. Trop., 81:18-28. (1962) (135: I 2; V B 1.)
- Keay, R. W. J. (1960) An example of northern Guinea zone vegetation in Nigeria, Niger. For. Inform. Bull., No. 1, 46 pp. (154: I 3; III E 0,1; IV D 2.)
- Keay, R. W. J. (1949) An example of Sudan zone vegetation in Nigeria, Jour. of Ecol., 37:335-364. (154: I 3; III D 0; IV C 3; IV D 2.)
- Keay, R. W. J. (1959) An outline of Nigerian vegetation, Federal Government Printer, Lagos, 46 pp. (154: I 3; IV D 1.)
- Keay, R. W. J. (1959) Derived savanna - derived from what? Bull. IFAN, Sér. A., Sci. nat., 21:477-483. (154: I 2; III E 0,1; III G 0.)
- Killick, H. J. (1959) The ecological relationships of certain plants in the forest and savanna of Central Nigeria, Jour. of Ecol., 47:115-127. (154: I 4; IV D 3.)
- Lamb, A. F. A. (1942) The Kurmis of Northern Nigeria, Farm and Forest, Land Use and Rural Planning in West Africa, 3. No. 4:187-192. (154: I 2; III G 0; V A 3.)

- Leneuf, N. and F. Aubert (1956) Sur l'origine des savanes de la basse Côte d'Ivoire, C. R. Ac. Sci., 243, sept. 17, 1956:859-860. (134: I 2; IV C 3; IV D 1.)
- Lynn, C. W. (1937) Agriculture in North Mamprusi, Department of Agriculture, Bull. No. 34, Accra, Ghana, 93 pp. (153: I 3; IV A 3; IV D 0; V B 2; V C 0.)
- MacDonald, K. R. (1944) The devastation of Africa by fire, Farm and Forest, Land use and Rural Planning in West Africa, 5, No. 2:22-25. (154: I 1; II B 0; V A 2,3; V B 2,3.)
- MacKay, J. H. (1936) Problems of ecology in Nigeria, Empire Forestry Jour., 15, No. 2:190-200. (154: I 2; III G 0; IV D 1,3b.)
- McCulloch, M. (1950) Ethnographic survey of Africa, Western Africa, Part II, Peoples of Sierra Leone Protectorate, Int. Afr. Institute, London, 102 pp. (152: I 2; II A 2; IV A 3; IV C 0; V B 0,2.)
- McElderry, J. C. K. (1942) A forest reservation survey in Pategi Emirate, Farm and Forest, Land Use and Rural Planning in West Africa, 3, No. 1:23-27. (154: I 1; IV D 3b.)
- Mangenot, G. (1950) Les forêts de la Côte d'Ivoire, Bull Soc. Bot. Fr., 97, No. 7-9:156-157. (134: I 3; IV D 1.)
- Mangenot, G. (1958) Les recherches sur la végétation dans les régions tropicales humides de l'Afrique Occidentale, Study of Tropical Vegetation, UNESCO (Proc. of Kandy Symposium), pp. 115-126. (120: I 2; IV D 1.)
- Mangin, Eugène (1921) The Mossi, essay on the manners and customs of the Mossi people in the Western Sudan, (in Fr.), Augustin Challamel, Paris, 116 pp. (136: I 3; II A 2; V B 2.)
- Masson, H. (1949) La température du sol au cours d'un feu de brousse au Sénégal, Bull. Agric. Congo Belge 40: 1933-1940, (also: Agron. Trop. 3:174-179, 1948). (132: I 4; II B 2; III A 1; IV B 0; IV C 3.)
- Maugham-Brown, H. (1943) The Sei bush belts of Sierra Leone, Farm and Forest, Land Use and Rural Planning in West Africa, 4, No. 1:8-9. (152: I 1; V A 3; V B 2.)
- Mensbruge, G. de la (1961) La lutte contre les feux: parcelles d'essai-restauration forestière, Centre Technique Forestier Tropical, Nogent-sur-Marne, 25 pp. (154: I 2; V B 1.)
- Moore, A. W. (1960) The influence of annual burning on a soil in the derived savanna zone of Nigeria, 7th Inter. Congress Soil Sci., Madison, 1960, Trans., 4:257-264. (154: I 4; III D 0,1,2.)

- Morgan, W. B. (1959) Agriculture in southern Nigeria (excluding the Cameroons), Economic Geog., 35, No. 2: 138-150. (154: I 0; V A 3.)
- Nadel, Siegfried Frederik (1942) A black Byzantium: the Kingdom of Nupe in Nigeria, Oxford. London, 420 pp. (154: I 3; II A 2; IV A 3; IV D 1,3b.)
- Nash, T. A. M. (1944) The probable effect of the exclusion of fire upon the distribution of tsetse (Glossina spp.) in northern Nigeria, Farm and Forest, 5:8-12. (154: I 2; V B 4.)
- Nigeria, Oil palm research station, (1946) Annual Report 1944. Nigeria Agric Dept, 24 pp. (154: I 2; III D 0.)
- Nigeria, (1958) Annual report on the forest administration of the Northern Region of Nigeria for 1957-1958, Government Printer, Kaduna, 46 pp (154: I 4; IV D 0,1.)
- Nye, P. H. (1959) Some effects of natural vegetation on the soils of W. Africa and on their development under cultivation. Tropical Soils and Vegetation: UNESCO Abidjan Symposium 1959, pp. 59-63. (120: I 2; III B 0; III G 0; IV C 3.)
- Paques, Viviana (1954) Les Bambara, Monographies Ethnologiques Africaines, Presses Universitaires de France, Paris, 124 pp. (130: I 3; II A 2; V B 2.)
- Perriguet, N. (1961) Les travaux de protection contre les feux dans l'inspection forestière de Bamaka (Soudan), Proc Seconde Conf. For. Inter afric., Pointe Noire, 1958, 2:643-653. (130: I 2; III E 0,1; V B 1.)
- Pitot, A. (1949) Végétations et sols et leur problèmes en A.O.F., Bull Agric. Congo Belge, 40, No. 1,2,3. (Reprint: 11 pp.) (130: I 1; III D 0,2,3; III E 0; IV A 3)
- Pitot, Albert (1952) L'homme et les sols dans les steppes et savanes d'A.O.F., Cahiers d'Outre-Mer. 5:215-240. (130: I 3; III D 0; III E 0; III G 0; IV D 3b; V B 2.)
- Pitot, A. (1953) Feux sauvages, végétation et sols en A.O.F., Bull. IFAN 15, No 4:1370-1383. (130: I 1; III A 0,1,2; III E 0,1; V A 1; V B 0.)
- Porteres, R. (1950) Problèmes sur la végétation de la basse Côte d'Ivoire, Bull. Soc. Bot. Fr., 97, No 7-9: 153-156. (134: I 3; IV D 3.)
- Ramsay, J. M. and R. Rose Innes (1963) Some quantitative observations on the effect of fire on the Guinea savanna vegetation of northern Ghana over a period of eleven years, Sols africains, 8, No. 1:41-85. (153: I 4; II A 2; II B 0,2,3; III B 0,2; III E 0,1,2; III G 0; IV A 0,1,2; IV C 0,3; IV D 0,2; V A 0,2; V C 1.)

- Renard, M. (1949) Les feux de brousse du Soudan, Bull. Agric. Congo Belge, 40:1919-1932. (130: I 2; II A 2; III E 0; III D 2; IV A 0,1,2; IV B 0; IV D 0; V A 2; V B 1,2,3,4.)
- Richard-Molard, Jacques (1956) Afrique occidentale française, Berger-Levrault, Paris, 252 pp. (130: I 1; IV A 0,1; IV C 0; IV D 0; V A 0,1,3.)
- Richards, P. W. (1939) Ecological studies of the rainforest of southern Nigeria, Jour. of Ecol., 27:1-61. (154: I 3; IV D 1.)
- Richards, P. W. (1957) Ecological notes on West African vegetation, Jour. of Ecol., 45, No. 2:563-577. (120: I 3; III B 0; IV D 1,3b.)
- Ross, R. (1954) Ecological studies on the rainforest of southern Nigeria, III: Secondary succession in the Shasha Forest Reserve, Jour. of Ecol., 42:259-282. (154: I 3; III E 0,1; IV A 0,1.)
- Schnell, R. (1952) Contribution à une étude phytosociologique et phytogéographique de l'Afrique occidentale: les groupements et les unités géobotaniques de la région guinéenne, Mém. IFAN, Mélanges Botaniques, 18:45-235. (133: I 4; IV D 2.)
- Schnell, Raymond (1950) La forêt dense: introduction à l'étude botanique de la région forestière d'Afrique occidentale... Paul Lechevalier, Paris, 531 pp. (120: I 2; III B 0; III G 0; IV D 1.)
- Schnell, R. (1957) Remarques sur les forêts des montagnes ouest-africaines (Guinée et Côte d'Ivoire), et leur individualisation floristique, Bull. Jard. Bot. de l'Etat., 27, No. 2:279-287. (133, 134: I 4; IV D 2.)
- Schnell, R. (1952) Végétation et flore de la région montagneuse du Nimba, Mém. IFAN, No. 22, 604 pp. (132: I 4; III E 0,1; IV A 0,1; IV D 2.)
- Schnell, R. (1952) Végétation et flore des Monts Nimba (Afrique occidentale française), Vegetatio, 3:350-406. (130: I 4; III G 0; IV D 1.)
- Sénégal, (n.d.) Le climat du Sahel sénégalais. République du Sénégal, Ministère de l'Economie Rurale, Service des Eaux, Forêts, et Chasse, Dakar, 27 pp. (132: I 4; IV A 0,1.)
- Sénégal, (1957) Les sols et les terres, Rép. du Sénégal, Ministère de l'Economie Rurale, Service des Eaux, Forêts, et Chasses, Dakar, 12 pp. (132: I 1; IV C 3.)
- Sénégal, (n.d.) Nature et caractéristiques du feu de brousse au Ferlo, Rép. du Sénégal, Ministère de l'Economie Rurale Service des Eaux, Forêts, et Chasse, Dakar, 42 pp. (132: I 3; II A 1; II B 3,5; III D 0; V B 1,2.)

- Stamp, L. Dudley (1938) Land utilization and soil erosion in Nigeria, Geog. Rev., 28:32-45. (154: I 2; V A 3; V C 0.)
- Stebbing, E. P. (1937) The forests of West Africa and the Sahara, W. & R. Chambers, Ltd., London, 245 pp. (120: I 2; III A 0.)
- Stebbing, E. P. (1937) The threat of the Sahara, Jour. Roy. African Soc., Extra supplement, 35 pp. (120: I 2; III F 0,2; III G 0; IV C 2; IV D 0,3b.)
- Stewart, J. L. (1944) Grass burning in West Africa, Farm and Forest, 5:13-14. (154: I 1; V A 3; V B 1.)
- Taylor, C. J. (1960) Synecology and silviculture in Ghana, Thomas Nelson and Sons, Ltd., New York, 418 pp. (153: I 3; IV D 1)
- Trochain, J. (1940) Contribution à l'étude de la végétation du Sénégal, Mém. IFAN, No. 2, 433 pp. (132: I 4; IV A 0,1; IV C 3; IV D 1,2.)
- Vermeer, Donald E. (1964) Agricultural and dietary practices among the Tiv, Ibo and Birom tribes, Nigeria, Ph.D. dissertation, University of California, Berkeley, 279 pp. (154: I 4; II A 2; IV C 3; IV D 0,1,3b; V A 0,3; V B 0,1,2,3)
- Walker, H. O. (1962) Weather and climate [in Ghana], in: Wills, J. Brian, ed., Agriculture and land use in Ghana, Oxford Univ. Press, London, pp. 7-50. (153: I 3; IV A 0,1,2,3,4; IV B 0,1,2.)

Central Africa

- Adams, Captain John (1823) Remarks on the country extending from Cape Palmas to the River Congo, including observations on the manners and customs of the inhabitants, G. and W. B. Whittaker, London, 265 pp. (125: I 2; III A 0; IV B 1.)
- Adriaens, L. et G Waegemans (1943) Contribution à l'étude chimique des sols salins et de leur végétation en Ruanda-Urundi, Inst. Roy. Colon. Belge, Sect. des Sci. Nat. et Méd., Mémoires, 12, No. 3:1-186. (126, 127: I 2; III B 0; IV C 3; IV D 0,2; V B 2.)
- Airy-Shaw, H. K. (1947) The vegetation of Angola, Jour. of Ecol., 35:23-48. (122: I 4; IV D 1.)
- Alexandre, P. & J. Binet (1958) La groupe dit Pahouin (Fang-Boulou-Beti), Presses Universitaires de France, Paris, 152 pp. (141, 144: I 3; II A 1; V A 3; V B 2.)

- Andersson, Charles John (1861) The Okavango River: a narrative of travel, exploration and adventure, Harper and Brothers, New York, 414 pp. (122: I 2; II B 2,3.)
- Anonymous (1954) Essays de brûlage, Rapp. Inst. Nat. Etude Agron. Congo Belge 1953, pp. 397-398. (125: I 4; III E 0,1.)
- Anonymous (1962) La République du Tchad, Paul Bory, Monaco, 194 pp. (142: I 2; IV A 0,1; IV C 3; IV D 0; V A 0,1,3.)
- Anonymous (1952) Étude des 'nkunku' et de la recolonisation forestière en savane, Rapp. Inst. Nat. Etude Agron. Congo Belge 1951, pp. 53-54. (125: I 2; V A 3; V B 1.)
- Anonymous (1952) Influence des feux de brousse sur la régénération des coupes, Rapp. Inst. Nat. Etude Agron. Congo Belge 1951, pp. 46-47. (125: I 4; II B 3.)
- Anonymous (1953) Etudes des coupe-feu, Rapp. Inst. Nat. Etudes Agron. Congo Belge 1952, n.p. (125: I 2; V B 1.)
- Anonymous (1953) Influence des feux de brousse sur la régénération des coupes, Rapp. Inst. Nat. Etude Agron. Congo Belge 1952, (also Rapp. 1951), (125: I 4; II B 3; III B 0.)
- Bachelier, G. et al (1957) Les sols de savanne du Sud-Cameroun, Bull. Inst. Et. Centrafricaines, nouvelle série, 13-14:7-27. (144: I 3; III D 0,2,3; IV C 3.)
- Beguin, H. (1960) La mise en valeur agricole du Sud-Est du Kasai, Bull. INEAC, Sér. Scientif., No. 88, 289 pp. (125: I 3; III G 0,1; IV C 0,3; IV D 0; V A 3.)
- Boughey, A. S. (1963) Evolution of termite mounds in central Africa, Proceedings of the Central African Scientific and Medical Congress held at Lusaka, Northern Rhodesia, August 26-30, 1963, pp. 333-341. Pergamon Press, Oxford. (143: I 4; II B 4; III D 0; III E 0; IV C 1; IV D 2.)
- Boughey, A. S. (1955) The vegetation of the mountains of Biafra, Proc. Linn. Soc (London), 165, pp. 144-150. (144: I 4; IV D 2)
- Bourguignon, P., M Streel, J Calembert (1963) Prospection pédo-botanique des plaines supérieures de la Lufira (Haut-Katanga). Problèmes Sociaux Congolais (Bull. du Centre d'Etude des Prob. Soc. Indigenes), No. 60, pp. 7-106. Also: F.U.L.R.E.A.C., Univ. de Liège, 1960, 111 pp. (125: I 3; IV C 3; IV D 1,2.)
- Cameroun, Territoire du (1954) Recueil des textes législatifs et réglementaires relatifs aux régimes domaniaux, foncier forestier et à l'urbanisme, Impr. du Gouvernement, Yaounde, 189 pp. (144: I 4; V B 1.)
- Childs, Gladwyn Murray (1949) Umbunda kinship and character, Int. Afr. Inst. and Witwatersrand Univ. Press, London and New York, 245 pp. (122: I 3; II A 2; IV A 3.)

- Collin, A. (1951) Mise en défense contre les feux de brousse et réforestation des savanes du Bas-Congo, Conf. Forest Insterafr., Abidjan, déc. 1951. pp. 440-458 (124: I 1; V B 1.)
- de Coene, R. (1956) Agricultural settlement schemes in the Belgian Congo, Tropical Agriculture (Trinidad), 33, No. 1:1-12. (125: I 2; V A 3; V B 1)
- Delevoy, G. (1938) A propos de la régénération des savanes boisées, Inst. Roy. Colon. Belge, Bull. des Séances. 9:363-379. (125: I 4. III B 0.)
- Delvaux, J. (1958) Effets mesures des feux de brousse sur la forêt claire et les coupes à blanc dans la région d'Elisabethville, (1950-1951 à oct 1955), Bull. Agric Congo Belge, 49, No. 3:683-714. (125: I 4; III E 0; V B 2.)
- Dessens, Henri and Jean Dessens (1957) Etude préliminaire des cumulus et des pluies obtenues par convection provoquée, Puy de Dôme, Observatoire Bull., pp 47-60. (125: I 4; II A 2; III A 0; IV A 3; IV B 0)
- Dessens, Henri (1960) Orages sur un foyer convectif artificiel, Puy de Dôme, Observatoire Bull., No. 1: 27-30. (125: I 4; III A 0.)
- Devred, R. (1956) Les savanes herbeuses de la région de Mvuazi (Bas-Congo), Bull. Inf. INEAC, Ser. Scientif., No. 65, 115 pp (145: I 2; III E 0,1; III G 0,1; IV A 0,1; IV C 0; IV D 1.)
- Drachoussoff, V. (1947) Essai sur l'agriculture indigène au Bas-Congo, Bull. Agric. Congo Belge, 38, No. 3-4: 471-582. 783-880. (145: I 2; IV C 3; V A 0,1,3.)
- Dubois, J. (1957) Semis forestiers sur buttes incinérées. Leur importance dans les travaux de réforestation des savanes du Bas-Congo, Bull. Inf. INEAC, 6, fevr. 1957: 21. (125: I 2; IV C 1; IV D 2.)
- Dugast, Idelette (1955) Monographie de la tribue des Ndiki (Banan du Cameroun). Univ. Paris, Trav. et Mém. de l'Inst. d'Ethnologie. Vol. 58, Institut d'Ethnologie, Paris, 824 pp. (144: I 1; III B 0; V A 3.)
- Duvigneaud, P. (1956) Géographie de caractères et évolution de la flore soudano-zambézienne, Part III: Les Combretum arborescents des savanes et forêts claires du Congo méridional, Bull. de la Soc. Roy. de Bot. de Belg., 88: 59-90. (125: I 4; IV D 1.)
- Duvigneaud, P. (1953) La flore et la végétation du Congo méridional, Travaux du Laboratoire de Botanique Systematique et de Phytogéographie de l'Université Libre de Bruxelles, Publ. No. 2. (Also in: Lejeunia 16:95-124. (125: I 3; IV D 2.)

- Duvigneaud, P. (1958) La végétation du Katanga et de ses sols métalifères, Bull. de la Soc. Roy de Bot. de Belg., 90:127-286 (125: I 3; IV C 3; IV D 1.)
- Duvigneaud, P. (1953) Les formations herbeuses (savanes et steppes) du Congo méridional, Les Naturalistes Belges, 34:66-75. (125: I 2; III E 0,1; IV D 1.)
- Duvigneaud, P. (1949) Les savanes du Bas-Congo: essai de phytosociologie topographique, Lejeunia, 10:192 pp. (125: I 4; IV D 2.)
- Everaerts, E. (1939) Monographie agricole du Ruanda-Urundi, Bull. Agric. Congo Belge, 30:343-396. (126, 127: I 1; III B 0; IV D 0.)
- Evers, E. (1954) Burning and not burning in the cultivation of Hevea, (in French), Bull. Inst. Etud. Agron. Congo Belge, 3:217-224, In: Bull. Agric. Congo Belge, 45, No. 4. (125: I 3; III D 1,2,3.)
- Focan, A., W. Kuczarow and H. Laudelout (1950) L'influence de l'incinération sur l'incidence des maladies radiculaires: observations préliminaires, Bull. Agric. Congo Belge, 41: 921-924. (125: I 4; III E 0.)
- Germain, R. (1954) Considérations agrostologiques relatives au Congo belge et au Ruanda-Urundi, Bull. Inf. INEAC, 3, No. 6:347-366. (125: I 3; IV D 1.)
- Germain, R. (1949) Reconnaissance géobotanique dans le nord du Kwango, Publ. INEAC, Sér. scientif. No. 43, 22 pp. (125: I 3; III G 0; IV A 0,1; IV C 0; IV D 1.)
- Gillet, H. (1962) Vegetation, agriculture and soil of central Chad (Feuilles de Mongo-Melfi-Bokow-Guera), (in French), Jour. d'Agr. Trop. et Bot. Appl., 9, No. 11-12:451-501. (142: I 3; IV A 0,1; IV C 0,3; IV D 1; V A 3.)
- Gossweiler, John and F. A. Mendonça, (1939) Carta fito-geografica de Angola, Republica Portuguesa, Ministerio das Colonias, Edicão do Governo Geral de Angola, Lisbon, 243 pp. (140: I 3; IV D 1,2,3b.)
- Guillemin, R. (1956) Évolution de l'agriculture autochtone dans les savanes de l'Oubangui, Agr. Trop., (Paris), 11, No. 1:39-61, No. 2:143-176, 279-309. (143: I 2; IV A 0,1; IV C 0; IV D 0.)
- Hambly, Wilfred D. (1934) The Ovimbunder of Angola, Anthropology Series, 21, No. 2:87-362, Field Museum of Natural History, Chicago. (122: I 3; II A 2; IV B 0; V A 3; V B 2.)

- Henrard, P. (1939) Réaction de la microflore du sol aux feux de brousse, Publ. INEAC Bruxelles, 23 pp. (125: I 3; III D 3.)
- Humblet, L. (1958) La mise en protection de jachères dans le Haut-Ituri, Confér. Interafr. Forestière, 2^e session, juillet 1958, Communications présentées par le Congo et la Ruanda-Urundi, Bruxelles, pp. 86-98. (124: I 3; III E 0,1.)
- Jacques-Felix, H. (1961) Caractères des prairies d'altitude en Afrique occidentale, J. d'Agr. Trop. et Bot. Appl., 8, No. 6-7:229-235. (144: I 3; IV D 2.)
- Jacques-Felix, H. (1947) L'agriculture des noirs du Cameroun, une forme particulière de l'écobouage, Agr. Trop., 2:180-182. (144: I 2; III D 0; III G 0; V B 1.)
- Kellogg, C. E. and F. D. Davol (1949) An exploratory study of soil groups in the Belgian Congo, Publ. INEAC, Sér. scientif., No. 46, 73 pp. (124: I 3; IV C 3.)
- Kevers, G. (1950) Contribution à l'étude pédo-botanique d'une région du Haut-Lomami (Congo belge), Bull. Agric. Congo Belge, 41, No. 2:256-360. (124: I 3; IV D 1.)
- Kiwak, C. and P. Duvigneaud, (1953) Etude sur l'écomorphologie des Graminées des formations herbeuses du Bas-Congo, Bull. de la Soc. Roy. de Bot. de Belg., 86:91-104. (125: I 4; IV D 2.)
- Koechlin, Jean (1961) La végétation des savanes dans le sud de la République du Congo (Capitale Brazzaville), Inst. de Rech. Scientif. au Congo, Brazzaville, Montpellier, 310 pp. Also publ. by: Cffice de la Recherche Scientifique et Technique d'Outre-Mer (ORSTOM), Paris, 310 pp. (145: I 2; III D 0; III G 1; IV A 0,1; IV C 3; IV D 1,2.)
- Koechlin, J. (1956) Rapport de mission botanique dans le territoire du Tchad, Bull. Inst. d'Etudes Centrafricaines, nouvelle série, 12:133-199. (142: I 4; IV D 2.)
- La Documentation Française (1952) French Equatorial Africa, La Documentation Française, 47 pp. (145: I 1; II A 2; II B 1; IV D C,2.)
- Lebrun, J. (1958) Aspects de végétation, Belg. d'Outre-Mer, 3, No. 278:301-305. (125: I 2; II B 2; IV D 0.)
- Lebrun, J. and G. Gilbert (1954) Une classification écologique des forêts du Congo, Publ. de l'Inst. nat. pour l'ét. agron. du Congo belge, Sér. Scientif., No. 63, 89 pp. (124: I 4; IV D 1.)
- Lefevre, M. A. (1955) La vie dans la brousse du Haut-Katanga, Bull. de la Soc. Belge d'Etudes Géographiques, 24, fasc. 2, 181 pp. (125: I 4; IV A 0,1; IV C 3; IV D 0,1; V A 0,3; V B 3.)

- Léonard, A. (1962) Les savanes herbeuses du Kivu, Publ. INEAC, Ser. scientif. No. 95, 87 pp. (124: I 4; IV C 3; IV D 1.)
- Léonard, J. (1953) Les divers types de forêts du Congo Belge, Symposium AETFAT, Bruxelles, 1951, pp. 81-93. also: Lejeunia, 16:81-93. (124: I 3; IV D 1.)
- Letouzey, M. (1949) Feux précoces au Cameroun, Bull. Agric. Congo Belge, 40:1913-1918. (144: I 2; III E 0; III G 1; V A 0; V B 1,3.)
- Liben, L. (1958) Esquisse d'une limite phytogéographique qu'inéozambézienne au Katanga occidental, Bull. Jard. Bot. de l'Etat, 28, No. 3:299-305. (125: I 3; IV D 2.)
- McCulloch, Merran (1952) The Ovimbunder of Angola, Ethnographic Survey of Africa, West Central Africa, Part XI, Int'l. African Institute, London, 50 pp. (122: I 3; II A 2; IV A 3; V B 2.)
- Maes, J. (1924) Notes sur les populations des bassins du Kasai, de la Lukenie, et de Lac Léopold II, Annales du Musée du Congo Belge, Nouvelle série, 1, fasc. 1, Brussels, 212 pp. (125: I 1; IV D 2; V A 3; V B 0.)
- Maire, R. and T. Monod (1950) Etudes sur la flore et la végétation du Tibesti, Mém. IFAN, No. 8, 141 pp. (142: I 4; IV D 2.)
- Maitland, T. D. (1932) Grassland vegetation of the Cameroons Mountain, Kew Bull. 1932, pp. 417-425. (144: I 4; IV D 2.)
- Maréchal, Ph. (1958) Notes sur les savanes du Kwango-Kwilu, Confér. Interafr. Forestière, 2^e session, Juillet 1958, Communications présentées par le Congo et le Ruanda-Urundi, Bruxelles, pp. 27-33. (125: I 3; IV D 1; V B 1,2.)
- Mullenders, W. (1954) La végétation de Kaniama (entre-Lubishi-Lubilash, Congo belge), Publ. INEAC, Sér. scientif., No 61, 499 pp. (125: I 3; III E 0,1; IV A 0,1; IV C 3; IV D 2.)
- Murat, M. (1937) Végétation de la zone prédesertique en Afrique centrale (Région du Tchad), Bull. Soc. Hist. Nat. Afr. Nord, 28:19-83. (142: I 4; IV D 2.)
- Nanson, A. and M. Gennart (1960) Contribution à l'étude du climax et en particulier du péloclimax en forêt équatoriale congolaise, Bull. Inst. Agron. Gembloux, 28:287-342. (125: I 3; III C 3; IV D 0.2,3c.)
- Neviere, E. (1959) Relations entre les courants rapides et les types de temps en Afrique équatoriale, Météorologie Nationale, Monographies, No 14-30. (143: I 4; IV A 2,3,4; IV B 1,2.)

- Pagès, G. (1933) Un royaume hamite au centre de l'Afrique: au Ruanda sur les bords du Lac Kivu (Congo belge), Inst. Roy. Col. Belge, Section des Sci. Mor. et Pol., Mémoires, Collection in 8°, Vol. I. Bruxelles, 704 pp. (127: I 1; II A 2; IV A 3.)
- Peeters, Leo (1963) La géographie du pays Logo au sud d'Aba (Rép. Congo), Cemubac. Bruxelles, 155pp. (125: I 4; IV A 0,1,2; IV C 0,2,3.)
- Pire, J. et al. (1960) L'intensité des pluies au Congo et au Ruanda-Urundi, Acad. Roy. des Sci. d'O-M., Cl. des Sci. Techn.. (Bruxelles), Mémoires, 6, 135 pp. (125, 126, 127: I 4; IV A 0.)
- Quarre, P. (1943) Contribution to study of problem of bush fires for Haut Katanga, East African Agric. Jour., 9:118-120. (125: I 2; III E 0,1.)
- Receveur, M. (1949) Notes sur: 1^e, Les feux de brousse, et 2^e, Rotation des pâturages et transhumance saisonnière au Tchad, Bull. Agric. Congo Belge, 40:1951-1964. (142: I 2; III G 0; IV A 0,1; IV C 1; IV D 0; V A 0,3; V B 2.)
- Renier, M. (1946) La réforestation naturelle des savanes du Kwilu, Bull. Agric. Congo Belge, 37, No. 4:801-808. (125: I 1; III G 0.)
- Robert, Maurice (1956) Géologie et géographie du Katanga, [Union Minière], Bruxelles, 620 pp. (125: I 3; IV A 0,2,3; IV D 0,1)
- Samuel, P. (1950) Agriculture équatoriale bantou et agriculture européenne, Bull. Agric. Congo Belge, 41, No. 3:519-622. (125: I 1; V A 3.)
- Sautter, Gilles (1955) Notes sur l'agriculture des Bakamba de la Vallée du Niari, Bull. Inst. d'Études Centrafricaines, Nouvelle série, 9:67-105. (143: I 2; IV A 0,1; IV C 3; V A 3; V B 2.)
- Schmitz, A. (1963) Climax et forêts claires du Parc National de l'Upemba, Publ. de l'Université d'Élisabethville, 6:57-68. (125: I 1; II B 0.)
- Schmitz, A. (1958) Dégradations consécutives aux feux sauvages dans le Haut-Katanga - remèdes apportés, Confér. Interafr. Forestière, 2^e session, juillet 1958, Communications présentées par le Congo et le Ruanda-Urundi, Bruxelles, pp. 104-111. Also in: Bull. Agric. Congo Belge, 49, No. 4:1031-1038. (125: I 4; III E 0,1; III G 0.)
- Schmitz, A. (1952) Note sur l'expérimentation forestière portant sur l'effet du feu dans le Haut-Katanga (Congo belge), Conf. Forest. Interafric., Abidjan 1951, Proc., pp. 401-412. (125: I 4; III E 0,1.)

- Schmitz, A. (1962) The "muhulu" of southern Upper Katanga, (in French), Bull. Jard. Bot. de l'Etat, 32, No. 3:221-298. (125: I 4; IV D 2.)
- Sillans, R. (1952) Contribution à l'étude phytogéographique des savanes du Haut-Oubangui (Note préliminaire sur la végétation des termitières géantes), Bull. Soc. Bot. Fr., 99:2-4. (143: I 3; IV C 0; IV D 0,1.)
- Sillans, R. (1958) Les savanes de l'Afrique Centrale: Essai sur la physionomie, la structure et le dynamisme des formations végétales ligneuses des régions sèches de la République Centrafricaine, Pau, Lechevalier, Paris, 424 pp. (143: I 3; IV A 0,1; IV C 2,3; IV D 0,1.)
- Thomas, R. (1950) Essai de classement des formations congolaises à végétation aborescente d'après le groupement de leurs indices mensuels d'aridité, Bull. Agric. Congo Belge, 2:373-397. (125: I 3; IV D 1.)
- Thomas, R. (1942) Les limites climatiques de la cuvette congolaise et le système forestier bantou envisagé sous l'angle de la protection de la forêt, Bull. Agric. Congo Belge, 30:486-499. (125: I 3; IV A 0,1; IV D 1.)
- Tillon, R. (1961) Etude d'une parcelle de savane mise en défens (Républ. Centrafricaine): Reboisement artificiel ou naturel? Bois et For. de Trop., 77:13-21. Publ. also by: Directions des Eaux et Forêts, Centre Technique Forestier, République Centrafricaine, 11 pp. (143: I 4; III A 0,1; III E 1.)
- Tisserant, R. P. C. (1953) L'agriculture dans les savanes de l'Oubangui, Bull. Inst. d'Etudes Centrafricaines, 6:209-273. (143: I 1; V A 3.)
- Tondeur, M. G. (1955) Shifting cultivation in the Belgian Congo, Unasylva, 9, No. 2:67-71. (125: I 2; IV C 0, 2,3; V A 3.)
- Trochain, Jean-L. and J. Koechlin (1958) Les pâturages naturels du sud de l'A.E.F., Bull. Inst. d'Etudes Centrafricaines, Nouvelle série, 15-16:59-83. (140: I 3; II A 1; III B 0. IV D 0.)
- Union Professionnelle des Eleveurs du Congo Belge (1949) L'incendie méthodique des pâtures dans les grands élevages de bovidés au Congo, Bull. Agric. Congo Belge, 40:1941-1944 (125: I 1; V B 1,2,3.)
- Usim, H. A. (1964) Status of forest fires in West Cameroon, Report prepared at end of course given by Fed. Forestry Dept. under A. A. Brown, Boston University, 7 pp. (mimeogr.) (144: I 3; II A 2; III B 0; III G 0,1; IV A 3; IV C 3; IV D 0; V B 2.)

- Boughey, A. S. (1961) The vegetation types of Southern Rhodesia: a reassessment, Rhodesia Scientif. Assoc., Proc. and Trans., 49:54-98. (177: I 3; IV D 2.)
- Boughey, A. S., P. E. Munroe, J. Meiklejohn, R. M. Strang, and M. J. Swift (1964) Antibiotic reactions between African savanna species, Nature, 203, No. 4951:1302-1303. (176, 177: I 3; III E 1.)
- Brasnett, N. V. (1950) [Review of] Uganda Protectorate: Annual Report of the Forest Department for the year ended 31st December, 1949, Government Printer, Entebbe, 54 pp. in: Empire Forestry Review, 29:388-390. (174: I 1; V B 1.)
- Breitenbach, F. von (1961) Forests and woodlands of Ethiopia: a geobotanical contribution to the knowledge of the principal plant communities of Ethiopia, with special regard to forestry, Ethiop. For. Rev., 1:5-16. (164: I 3; IV D 1.)
- Buechner, H. K. and H. C. Dawkins (1961) Vegetation changes induced by elephant and fire in Murchison Falls National Park, Uganda, Ecology, 42, No. 4:752-766. (174: I 4; II B 3; III A 0; III G 0; IV D 0; V B 1,2.)
- Burbridge, A. B. (1938) Uncontrolled grass and forest fires, Rhod. Agric. Jour., 35:701-707. (176, 177: I 0; V A 2.)
- Burnett, J. R. (1948) Crop production. in: Tothill J. D. ed., Agriculture in the Sudan, pp. 275-301. Oxford University Press, London. (166: I 3; II A 2; IV D 3; V A 3, V B 0,2; V C 0.1)
- Burtt, B. D. (1942) Some East African vegetation communities, Jour. of Ecol., 30:65-146. (171: I 2; III D 0; III E 0, 1,2; III G 0; IV D 2.)
- Butt, Audrey (1952) The Nilotes of the Anglo-Egyptian Sudan and Uganda, Ethnographic Survey of Africa, East Central Africa, International Africa Institute, pp. 1-4, 134-158, 190-193. (166: I 3; II A 2; IV D 0,3; V B 2.)
- Catford, J. R. (1951) Katiri cultivation in the Moru district of Equatoria, Sudan Notes and Records, 32:106-112. (166: I 3; V A 3; V B 0,2.)
- Chidzero, B. T. G. (1961) Tanganyika and international trusteeship, Oxford University Press, London, 286 pp. (173: I 1; V A 0.)
- Chini, Renato (1942) Aspetti agricoli della zona centrale e meridionale del territorio dei Beni Sciangu, Reprint from: Agricoltura Coloniale, Anno XXXVI, No. 9, Regio Istituto Agronomico per l'Africa Italiana, Firenze, 7 pp. (164: I 1; IV D 0.)

Eastern Africa

- Allan, William (1949) Studies in African land usage in Northern Rhodesia, Rhodes-Livingstone Papers, No. 15, Oxford University Press, Capetown, London, New York, 86 pp. (176: I 3; IV D 0.2; V A 3; V B 2.)
- Alvino, G. (1939) Panorama forestale del Hararino, Reprint from: Agricoltura Coloniale, Anno XXXIII, 1939 XVII, Numero 5, Regio Istituto Agronomico per l'Africa Italiana, Firenze, 10 pp. (164: I 1; IV D 0; V A 1,3.)
- Andrews, F. W. (1948) The vegetation of the Sudan, in: Tothill, J. D., ed., Agriculture in the Sudan, pp. 32-61. Oxford University Press, London. (166: I 3; IV D 0.1,2; IV C 0,1,3.)
- Anonymous (1950) Effect of fire on teak, Report, Forestry Division, Sudan, 1949, p. 29. (166: I 3; III G 0.)
- Anonymous (n.d.) Effect of fire on teak, Rep. For. Div. Sudan, 1949-1950, p. 29. (166: I 3; III G 0.)
- Astle, W. L. (1965) The grass cover of the Chambeshi Flats, Northern Province, Zambia, Kirkia, 5:37-48. (176: I 3; II A 2; IV C 3; IV D 1.)
- Barbour, K. M. (1964) North and south in Sudan, a study in human contrasts, Annals, A.A.G., 54:209-226. (166: I 4; V A 0.)
- Barbour, K. M. (1953) Peasant agriculture in the savannah belt of the Anglo-Egyptian Sudan, University College. Khartoum, 66 pp. (166: I 2; III B 0; III E 3; IV D 0, 3b; V A 3; V B 1,2.)
- Barnes, J. A. (1951) A. Marriage in a changing society, and B. A study in structural change among the Fort Jamison Ngoni, Rhodes-Livingstone Papers, No. 20, Oxford University Press, New York, Capetown, London, 141 pp. (178: I 2; II A 2; III B 0; III D 0; IV A 3; IV B 1, 4; IV D 0; V B 0.)
- [Blixen Finecke, Baronesse Karen Christense (Dinesen)]
"Isak Dinesen" (1938) Out of Africa, Random House, New York, 389 pp. (172: I 1; II A 2; II B 0; V A 3.)
- Booth, G. A. (1952) Forests of Upper Nile Province, Sudan Notes and Records, 33, Part 1:113-128. (166: I 1; II B 2; III B 0; IV D 0; V B 1.)
- Booth, John (1905) Der Bezirk Ssongea, Beihefte zum Tropenpflanzer, 6, Heft 4/5:263-276. (173: I 0; IV D 0.)
- Boughey, A. S. (1963) Interaction between animals, vegetation, and fire in Southern Rhodesia, Ohio J. Sci., 63, No. 5:193-209. (177: I 3; II A 1; III E 0,1; III G 0; IV D 1.)

- Clements, J. B. (1933) The cultivation of finger millet (Eleusine coracana) and its relation to shifting cultivation in Nyasaland, Empire Forestry Jour., 12, No. 1: 16-20. (178: I 3; II A 1; V B 2.)
- Cockbill, Gerald F. (1955) Personal communication, in: Bartlett, H. H., Fire in relation to primitive agriculture and grazing in the tropics: annotated bibliography, 3 Vols., Ann Arbor, Univ. of Michigan, Dept. of Botany, 1955-1961. Ref. in Vol. II, 1957, p. 299. (177: I 2; II B 2; V A 3.)
- Cole, Monica M. (1963) Vegetation and geomorphology in Northern Rhodesia: an aspect of the distribution of the savana of central Africa, Geog. Jour., (London), 129, No. 3:290-310. (176: I 3; III G 0,1; IV C 0; IV D 2.)
- Corfield, F. D. (1938) The Koma, Sudan Notes and Records, 21:123-165. (166: I 0; V A 3.)
- Crowther, Frank (1948) A review of experimental work, in: Tothill, J. D. (ed.) Agriculture in the Sudan, pp. 439-592. Oxford Univ. Press, London. (166: I 3; II A 2; III B 0; IV C 2.)
- de Schlippe, Pierre (1955) Shifting cultivation in Africa: the Zande system of agriculture, Routledge and Kegan Paul, London. 304 pp. (166: I 3; II A 2; II B 0,2; III B 0; III C 0,1; III D 0,1,2; III E 0,1,2,3; III F 2; III G 0,1; IV A 0,1,2. IV B 0,2; V A 0,3; V B 0,1,2,4; V C 0,1.)
- de Schlippe, P., and B. L. Batwell (1955) Preliminary study of the Nyangwara system of agriculture, Africa, 25: 321-351. (166: I 4; II A 2; V B 2.)
- Deshler, Walter W. (1957) The Dodos country, a study of indigenous settlement in the semi-arid area of Uganda, Ph.D. dissertation. University of Maryland, 130 pp. (typescript). (174: I 4; II A 0,2; II B 0,4; III E 0,1,3; IV C 0,3; V A 0.)
- Edwards, D. C. (1940) A vegetation map of Kenya with particular reference to grassland types, Jour. of Ecol. 28:377-385. (172: I 4; IV D 2.)
- Edwards, D. C. (1950) Grassland research in Kenya, (Colloquium on grassland research, Paper IV), East African Agric. Jour., 15:208-211. (172: I 1; II B 0.)
- Eggeling, W. J. (1947) Observations on the ecology of the Budongo rain forest, Uganda. Jour. of Ecol., 34:20-87. (174: I 3; II B 3; IV B 0; IV D 0,1,2,3; V A 0.)
- Eggeling, W. J. (1958) The savannah and mountain forests of South Karamoja, Uganda. Imp. For. Inst. (Oxford) Paper No. 11, 14 pp. (174: I 3; III E 0,1; III G 0; IV D 2)

- Evans-Pritchard, Edward Evan (1940) The Nuer: A description of the modes of livelihood and political institutions of a Nilotic people, Clarendon Press, Oxford, 271 pp. (166: I 1; II A 1; V A 3.)
- Federation of Rhodesia and Nyasaland (196-) An agricultural Survey of Southern Rhodesia, Pt. 1: Vincent, V., and R. G. Thomas, The agro-ecological survey. 124 pp., Pt. II: Anderson, R., The agro-economic survey, 122 pp. (177: I 4; III E 0,1; III F 0; III G 0; IV A 0,1,2,4; IV C 0, 2,3; IV D 1,2,3b; V A 0,1,3; V B 2,4.)
- Ferguson, H. (1944) Deterioration of soils and vegetation in Equatoria Province with special reference to grass fires, Sudan Govt. Soil Conserv. Committee, Report, pp. 138-142. (166: I 2; III D 0,1,2; III E 0; III G 0; V B 1,2,3.)
- Ferguson, H. (1948) Equatoria Province, in: Tothill, J. D., (ed.), Agriculture in the Sudan, pp. 875-918, Oxford University Press, London. (166: I 3; II B 0; III D 0,1; III E 0,1; III F 2; V A 3.)
- Floyd, Barry N. (1960) Changing patterns in African land use in Southern Rhodesia, Rhodes-Livingstone Journal 25:40-58. (177: I 4; IV A 3; IV C 3; IV D 1; V A 0,3.)
- Friend, M. T., O. Kerfoot and R. M. Scott (1962) Kedong Ranch, East African Agr. and Forestry Research Organ. 1962, pp. 88-103. (172: I 1; IV D 0,3b.)
- Furness, C. N. (1965) Personal communication, (177: I 2; II A 2; II B 0,1,2,4; III D 0,1; III E 0,1; V B 0,2.)
- Gammon, D. M. (1962) Veld fire control. Rhodesia Agric. Jour., 59, No. 4:177-191. (177: I 3; II A 2; II B 0, 2,4,5; III A 2; III E 0,3; IV A 2; IV B 0,1,2; IV C 0, 1; V B 0,1.)
- Gardner, T. A. M. (1965) Extracts from Forest Department Annual Reports, Forest Department, Ministry of Natural Resources and Wildlife, Nairobi, 9 pp. (172: I 3; II A 0; II B 0,1,2; IV B 0; V B 2.)
- Gardner, T. A. M. (1965) Personal communication. (172: I 1; II A 2; IV A 3.)
- Gilliland, H. B. (1952) The vegetation of eastern British Somaliland, Jour. of Ecol., 40:91-124. (162: I 4; IV D 1.)
- Gillman, C. (1949) A vegetation-types map of Tanganyika territory, Geog. Rev., 39, No. 1:7-27. (173: I 3; IV D 1,3b.)

- Gleichen, Lieut. Col., Count (1905) The Anglo-Egyptian Sudan: a compendium prepared by officers of the Sudan government, Vol. I: Geographical, descriptive and historical, Vol. II: Routes, His Majesty's Stationery Office, London, 271 pp. (166: I 2; II A 0; II B 0,1, 2; IV D 0; V C 1.)
- Glover, H. M. (1953) Soil conservation in parts of Africa and the Middle East, Part I: African holiday, Part I (cont.): Tanganyika, Empire Forestry Rev., 32:222-225, 351-354. (173: I 1; V A 3.)
- Glover, P. E., J. Glover, and M. D. Gwynne (1962) Light rainfall and plant survival in East Africa, Pt. II: Dry grassland vegetation, Jour. of Ecol., 50, No 1: 199-206. (172: I 3; IV A 0.)
- Gomes e Sousa, Antonio de Figueredo (1949) Dendrologia de Moçambique. II. Essencias do Extremo Sul, Junta de Exportacao de Mocambique, Lourenço Marques, 130 pp. (179: I 1, IV C 2; IV D 0.)
- Gorrie, R. Maclagan (1935) The use and misuse of land, Clarendon Press, Oxford, 80 pp. (176: I 1; II B 2,3; V A 3; V B 1.)
- Hall, A. Daniel (1930) The improvement of native agriculture in relation to population and public health, Oxford University Press, London, 104 pp. (172, 326: I 2; V A 2,3; V B 2.)
- Harrison, M. N. and J. K. Jackson (1958) Ecological classification of the vegetation of the Sudan, Forest Bull., No. 2, 45 pp. (166: I 3; IV D 0.)
- Hemming, C. F. (1961) The ecology of the coastal area of northern Eritrea, Jour. of Ecol., 49:55-78. (164: I 3; IV A 1,2; IV D 1.)
- Hopkins, B. (1960) Rainfall interception by a tropical forest in Uganda, East African Agric. Jour., 25, No. 4:255-258. (174: I 4; IV A 3.)
- Huffnagel, H. P. (comp.) (1961) Agriculture in Ethiopia, FAO. Rome, 483 pp. (164: I 4; II A 2; II B 0; III B 2; III C 0,1,2,3; III D 0,1,2,3; III E 0; III F 0,2; III G 0,1; IV A 0,1,2,4; IV B 0; IV D 0,1,2,3; V A 3.)
- Huntingford, G. W. B. (1953) The Southern Nilo-Hamites, Ethnographic Survey of Africa. East Central Africa, Part VIII, Inter. African Institute, London, 147 pp. (172: I 3; II A 2; V B 2.)
- Hursh, C. R. and H. C. Pereira (1953) Field moisture balance in the Shimba Hills, Kenya, East Afric. Agric. Jour., 18:139-145. (172: I 2; III C 0,1; III G 0.)

- Ireland, A. W. (1948) The climate of the Sudan, in: Tothill, J. D., ed., Agriculture in the Sudan, pp. 62-83, Oxford University Press, London. (166: I 3; IV A 0,1,2,3,4; IV B 0,1.)
- Jackson, J. K. (1956) The vegetation of the Imatong Mountains, Sudan, Jour. of Ecol., 44:341-374. (166: I 2; IV C 3; IV D 2; V A 3.)
- Jasi, Anthony G. R. (n.d.) Report on forest fires and control, Uganda Forest Service, 2 pp. (mimeogr.). (174: I 1; II A 1; IV D 0; V B 1.)
- Junod, Henri A. (1927) The life of a South African tribe, Macmillan, London, Vol. I, 559 pp., Vol. II, 660 pp. (179: I 3; II A 2; V B 2.)
- Kenya, (n.d.) Kenya: Forest Report (1945-1962), Government Printer, Nairobi, (172: I 1; II B 2,5; III B 0.)
- Langdale-Brown, I. (1960) The vegetation of Buganda, Memoirs of Res. Div., No. 2, Uganda Dept. of Agriculture, 89 pp. (174: I 4; IV A 0,1; IV C 2; IV D 2.)
- Langdale-Brown, I. (1959) The vegetation of the Eastern Province of Uganda, Memoirs of Res. Div., No. 1, Uganda Dept. of Agriculture, 154 pp. (174: I 4; IV A 0,1; IV C 2; IV D 2.)
- Langdale-Brown, I. (1960) The vegetation of the Western Province of Uganda, Memoirs of Res. Div., No. 4, Uganda Dept. of Agriculture, 111 pp. (174: I 4; IV A 0,1; IV C 2; IV D 2.)
- LeBar, Frank M. (1950) Azande category summaries, HRAF Inc., New Haven, n.p. (166: I 3; II 2; V B 2.)
- Lemon, Paul C. (1964) Natural communities of the Malawi National Park (Nyida Plateau), Government Printer, Zomba, Malawi, 70 pp. (178: I 3; II A 2; III D 0,1; III E 0,1; III G 0; IV A 0,1; IV B 0,1,2; IV D 2; V B 1.)
- Lowe, John (1964) Personal communication, (177: I 2; II A 1,2; II B 1,2,3; III D 0; IV A 5.)
- March, G. F. (1936) The development of native agriculture in the Nuba mount in area of Kordofan Province, Anglo-Egyptian Sudan, Emp. Jour. of Exp. Agric., 4, 13:77-80. (166: I 1; V A 3; V B 1.)
- McLinden, D. T. (1954) The forester and the control of fire, Nyasaland Farmer and Forester, 2, No. 1:30-33. (178: I 0; II B 3.)
- Mair, Lucy P. (1934) An African people in the 20th century, Routledge, London. 299 pp. (174: I 3; V C 0.)

- Malawi (1965) Annual report of the Department of Forestry for the year 1962/1963, Ministry of Natural Resources, Zomba, Malawi. 73 pp. (178: I 3; II A 1,2; II B 0,1,4; IV A 0,1; V B 1; V A 3.)
- Masefield, G. B. (1948) Grass burning: some Uganda experience, East African Agric. Jour., 13, No. 3:135-138. (174: I 2; II A 0,1,2; II B 0,2,4,5; III D 0; III E 0; IV B 2; IV C 1; V A 3; V B 1,2,3,4; V C 1.)
- Meiklejohn, J. (1955) The effect of bush burning on the microflora of a Kenya upland soil, Jour of Soil Sci., 6:111-118, (172: I 3; III B 0; III G 0.)
- Mitchell, B. L. (1961-1962) Some notes on the vegetation of a portion of the Wankie National Park, Kirkia, 2: 200-209. (177: I 2; III E 0,1; IV C 1.)
- Northern Rhodesia (1962) Amended statement of the discussion held at Ndola on Dec. 14-15, 1961, on the effect of fire on unimproved land, Conservation Working Party of the Forest Department, Kitwe, 8 pp. (mimeogr.) (176: I 2; II A 1; IV D 2,3b.)
- Northern Rhodesia (1950) Burning to obtain regeneration, Report Forestry Dept. No. Rhodesia 1949, (176: I 3; IV D 3b.)
- Northern Rhodesia (1953) Fire breaks in Northern Rhodesia, Report Forestry Dept. No. Rhodesia 1952. (176: I 3; V B 1.)
- Northern Rhodesia (1951) Fire control, Report Forestry Dept. No. Rhodesia 1950, p. 7. (176: I 3; V B 2.)
- Nyasaland (1962) Annual Report of the Department of Forestry for the Year ended 31st December, 1961. Ministry of Natural Resources and Local Government, Zomba, Nyasaland, 57 pp. (178: I 3; II A 0,1; II B 0,1; III E 1; V A 0.)
- Owen, W. E. (1933) Food production and kindred matters amongst the Luo, Jour. E. Afr. and Uganda Nat. Hist. Soc., No. 49-50:235-249. (172: I 1; II A 0; IV A 3.)
- Parsons, D. J. (1960) The systems of agriculture practiced in Uganda, Northern systems, Pt. I: The Lango-Acholi System; Pt. II: The West Nile Systems, Uganda Department of Agriculture, Memoirs, Series 3, Kwanda Research Station, Kampala. 66 pp., (mimeogr.) (170: I 3; II A 2; III C 1; IV A 0,1,2, 4; IV D 0; V A 2; V C 0.)
- Parsons, D. J. (1960) Introduction and Teso systems, Uganda Department of Agriculture, Memoirs, Series 3, Kwanda Research Station, Kampala. 70 pp., (mimeogr.) (174: I 3; II A 2; IV A 0,1,2,3,4; IV C 1,3; IV D 0; V A 0,3, 4; V C 0.)

- Parsons, D. J. (1960) Montane systems, Uganda Department of Agriculture, Memoirs, Series 3, No. 4, Kwanda Research Station, Kampala, 30 pp. (mimeogr.) (174: I 3; II A 2; IV A 1,4; IV D 0; V A 3.)
- Parsons, D. J. (1960) The plantain-robusta coffee systems with a note on the plantain-millet-cotton areas, Uganda Department of Agriculture, Memoirs of the Research Division, Series 3, No. 2, The systems of agriculture practiced in Uganda, Kawanda Research Station, Kampala, 57 pp. (mimeogr.) (174: I 3; II A 2; II B 0; III C 1; III E 0, 1; III G 0,2; IV A 1,2,4; IV C 0; IV D 0; V A 0,3,4.)
- Parsons, D. J. (1960) The systems of agriculture practices in Uganda, Uganda Department of Agriculture, Memoirs, Series 3, No. 5, Kwanda Research Station, Kampala, 27 pp. (mimeogr.) (174: I 3; II A 2; II B 0; III C 1; III E 0, 1; III G 0,2; IV A 1,2,4; IV C 0; IV D 0; V A 0,3,4.)
- Perrins, J. R. (1939) Grass fires and fire-belt burning, Rhodesia Agric. Jour., 36:505-507. (176, 177: I 2; II A 2; II B 2,5; V B 1.)
- Phillips, J. F. V. (1930) Fire: its influence on biotic communities and physical factors in southern and eastern Africa, So. Afr. Jour. Sci., 27:352-367. (171, 190: I 2; II B 3; III G 0.)
- Phillips, John (1930) Some important vegetation communities in the Central Province of Tanganyika Territory (formerly German East Africa): a preliminary account, Jour. of Ecol. 18, No. 2:193-234. (173: I 2; II B 0; III B 0; IV D 1,3b.)
- Phipps, J. B. and R. Goodier (1962) A preliminary account of the plant ecology of the Chimanimani Mountains, Jour. of Ecol., 50:291-320. (177, 179: I 4; III E 0,1; III G 0; IV D 2.)
- Pichi-Sermolli, R. E. G. (1957) Una carta geobotanica dell'Africa orientale (Eritrea, Etiopia, Somalia), Webbia, 13:15-132. (162, 164, 165: I 3; IV D 1.)
- Pielou, E. C. (1952) Notes on the vegetation of the Rukwa Rift Valley. Tanganyika. Jour. of Ecol., 40:383-392. (173: I 4; II A 1; IV D 2.)
- Plowes, D. C. H. (1955) Veld burning: how, why, and when, Rhodesia Agric. Jour. 52, No. 5:380-394. (177: I 3; V B 1,2.)
- Ramsay, D. M. (1958) The forest ecology of central Dafur, For. Bull. For. Dept. Sudan, No. 1, 80 pp. (166: I 3; IV D 2.)
- Ratray, J. M. (1964) Personal communication. (177: I 3; IV D.)

- Rattray, J. M. (1954) Some plant indicators in Southern Rhodesia, Rhodesia Agric. Jour., 51:176-186. (177: I 3; IV C 3; IV D 2.)
- Rattray, J. M. (1957) The grasses and grass associations of Southern Rhodesia, Rhodesia Agric. Jour., 54, No. 3: 197-234. (177: I 3; IV D 2.)
- Rattray, J. M. (1961) Vegetation types of Southern Rhodesia, Kirkia, (Salisbury), 2:68-93. (177: I 4; IV D 2.)
- Rattray, J. M. and H. Wild (1961) Vegetation map of the Federation of Rhodesia and Nyasaland, Kirkia, (Salisbury), 2:94-104. (177, 178, 179: I 4; IV D 2.)
- Rattray, R. Sutherland (1907) Some folk lore stories and songs in Chinyanja, Society for Promoting Chris. Knowledge, London, pp. v-xiii, 85-164 in H.R.A.F. (178: I 1; V B 0,2.)
- Read, Margaret (1950) Children of their fathers: growing up among the Ngoni of Nyasaland. Yale University Press, New Haven, 176 pp. (178: I 3; II A 1; V B 2.)
- Reed, J. Gordon (1951) The Ila Buffalo drive, 1933, No. Rhodesia Jour., 1, No.4:62-66. (176: I 1; V B 3.)
- Republic of the Sudan, Forests Department (1954-1964) Annual reports (for the period inclusive 1953-1963), Forests Department, Republic of the Sudan, Khartoum, (var. paging). (166: I 4; II A 2; II B 0; III D 0,2; IV A 0; IV D 0,1.)
- [Rhodesia] Division of Forestry (1938) The control of veld fires, Rhodesia Agric. Jour., 35:243-246. (177: I 2; II A 2; IV A 0; V B 1.)
- Richards, Audrey I. (1948) Hunger and work in a savage tribe, The Free Press, Glencoe, Illinois, 238 pp. (176: I 1; V B 2.)
- Richards, Audrey I. (1939) Land labour and diet in Northern Rhodesia: an economic study of the Bemba tribe, Oxford University Press, London, 423 pp. (176: I 2; II A 2; V A 0,3.)
- Rogers, Pat (1959) Timber's big contribution to Copperbelt mining, Horizon, 1:4-8 (176: I 0; II B 0.)
- Scaetta, H. (1941) Les prairies pyrophiles de l'A.O.F., Rev. de Bot. Appl. et d'Agron. Tropicale, mai-juin 1941, pp. 221-240. (174, 126: I 3, II A 2; III E 0, 1; IV D 0,1,2.)
- Scott, J. D. (1952) The management of range pastures (veld) in Africa, Sixth Inter. Grasslands Cong., 1:477-483. (176, 177, 190: I 2; III G 0; V B 2.)

- Scudder, Thayer (1962) The ecology of the Gwembe Tonga. (Kariba Studies, Vol. II), Manchester University Press, Manchester, 274 pp. (176: I 1; V A 3; V B 2.)
- Sellick, N. P. (1959) Note on humidity and rainfall, in: Joint Symposium on Tropical Meteorology in Africa, Nairobi Kenya, Dec. 1959., 6 pp. (177: I 4; IV A 0,1,2,3; IV B 2.)
- Sherwood, J. H. (1948) Upper Nile Province, in: Tothill, J. D., (ed.), Agriculture in the Sudan, Oxford University Press, London, pp. 810-826. (166: I 3; III F 2; V A 3.)
- Simoons, Frederick J. (1960) Northwest Ethiopia: peoples and economy, University of Wisconsin Press, Madison, 230 pp. (164: I 1; II A 2; II B 2.)
- Smart, J. B. (1965) Personal Communication, (172: I 3; II A 2; II B 0,1,5; III E 1; III G 0,1.)
- Smith, E. W. and A. M. Dale (1920) The Ila speaking peoples of Northern Rhodesia, Macmillan, London. Vol. I; 423 pp, Vol. II, 433 pp. (176: I 3; II A 2; V B 1,2.)
- Smith, J. (1949) Distribution of tree species in the Sudan in relation to rainfall and soil texture, Bull. Minist. Agric., Sudan Govt., 4 pp. (166: I 2; IV A 0,1; IV C 3; IV D 0.)
- Southern Rhodesia (1959-1965) Fifth to tenth annual reports and accounts for the years 1958-1959, 1959-1960, 1960-1961, 1961-1962, 1962-1963, and 1963-1964. Forestry Commission. (177: I 3; II A 0,1; II B 0; IV D 1; V B 2,4.)
- Staples, R. R. (1945) Veld burning, Rhodesia Agric. Jour., 42, No. 1:44-52. (177: I 3; II A 2; III D 0; III E 1,3; IV D 0.)
- Tansanyika, Chief Conservator of Forests (1965) Personal communication, (173: I 2; II B 0.)
- Tempany, H. A. (1958) An introduction to tropical agriculture, Longmans, Green and Company, London, 347 pp. (176: I 2; III G 0,1; IV A 3; IV D 1; V A 3; V B 1,2.)
- Tew, Mary (1950) Peoples of the Lake Nyasa region, Ethnographic Survey of Africa, Part I, pp. 1-22, Oxford University Press, London. (179: I 3; II A 2; V B 2.)
- Thomas, A. S. (1945) The vegetation of some hillsides in Uganda: illustrations of human influence in tropical ecology, J. of Ecol., 33:10-43, 153-172. (174: I 2; III D 2; III E 0,1; III G 0.)
- Thomas, A. S. (1943) The vegetation of the Karamoja District, Uganda. Jour. of Ecol., 32, No. 2:149-177. (174: I 2; II A 2; II B 0; III D 0; III E 0,1; III G 0; IV A 0,1; IV C 3; IV D 2; V A 0,3)

- Thomas H. B. and Robert Scott (1935) Uganda, Oxford University Press, London, 552 pp. (174: I 1; IV D 1,3b.)
- Thompson, B. W. (1957) The diurnal variation of precipitation in British East Africa, Africa Highland Comm., Meteor. Dept., Tech. Memorandum, No. 8, 70 pp. (170: I 3; IV A 0; IV B 0,2.)
- Thompson, C. K. (1965) Personal communication (177: I 3; II A 2.)
- Thomson, J. R. (1950) Farming by fire, World Crops, 2:396-397. (166: I 1; III G 0; V B 1.)
- Tothill, J. D. (ed.) (1948) Agriculture in the Sudan, Oxford University Press, London, 973 pp. (166: I 3; II A 1; II B 0; III B 0; III E 0; III F 0; IV A 0,1,2,3,4; IV C 0,1,2,3; IV D 0,1,2,3a,c; V A 0,1,2,3; V B 0,1,2,3; V C 0,1.)
- Tothill, J. D. (ed.) (1940) Agriculture in Uganda, Oxford University Press, London, 551 pp. (174: I 2; III F 0,1,2; IV D 3b; V A 2.)
- Trapnell, C. G. (1959) Climatic types of vegetation in southern Kenya, Rep. E. Afr. Agric. For. Res. Organ. 1957, pp. 56-58. (172: I 2; IV C 3; IV D 2.)
- Trapnell, C. G. (1959) Ecological results of woodland burning experiments in Northern Rhodesia, Jour. of Ecol., 47:129-168. (176: I 3; II A 2; II B 0,2; IV D 0.)
- Trapnell, C. K. (1959) Ecology, climatic types of vegetation in southern Kenya, Rep. E. Afr. Agric. For. Res. Organ. 1958, pp. 42-47. (172: I 2; IV C 3; IV D 2.)
- Trapnell, C.G. (1957) The effects of fire in Brachystegia-Isoberlinia woodlands (Northern Rhodesia), Rep. East Afr. High Comm. Agric. and Forestry Res. Organ. 1957. pp.54-55, 57-58. (176: I 3; IV B 1; IV C 3; IV D 0,3b.)
- Trapnell, C. G. (1943) The soils, vegetation and agriculture of northeastern Rhodesia, Report of the Ecological Survey, Government Printer, Lusaka, Northern Rhodesia, 111 pp. (176: I 4; V A 3; V B 2.)
- Trapnell, C. G. and J. N. Clothier (1937) The soils, vegetation and agricultural systems of northwestern Rhodesia, Report of the Ecological Survey, Government Printer, Lusaka, 69 pp. (176: I 2; III B 0; IV C 3.)
- Trapnell, C. G., J. D. Martin and W. Allan (1948) Vegetation-soil map of Northern Rhodesia...with an explanatory memoir by C. G. Trapnell, Government Printer, Lusaka, Northern Rhodesia, 20 pp. (176: I 3; IV D 1.)
- Troup, L. G. (1953) Enquiry into the general economy of farming, Government Printer, Nairobi, 76 pp. (172: I 3; IV A 0; IV D 1.)

- Uganda (1951) Effect of closing savanna to grazing, Report Forestry Dept. Uganda, 1949, 1950. (174: I 3; III G 0; V B 2.)
- Uganda (1963) Annual report of the Forest Department 1961/1962. Published by authority, 82 pp. (174: I 1; V B 1.)
- Uganda Protectorate (n.d.) Annual report of the Forest Department 1960/1961, Government Printer, Entebbe, 76 pp. (174: I 1; V B 2.)
- Uganda Protectorate (1959) Annual report of the Forest Department for the year ended Dec. 31, 1958, Government Printer, Entebbe, 80 pp. (174: I 1; V B 2.)
- Uganda Protectorate (1950-1957) Annual report of the Forest Department for the years ended 31st December 1950-1957, Government Printer, Entebbe, various pagings. (174: I 1; II B 3; V B 2.)
- United Republic of Tanzania (1960-1965) Annual Reports of the Forest Division, 1959-1964, Survey Division, Ministry of Lands, Settlement and Water, various pagings. (173, 175: I 3; II A 2; II B 0; III E 0; IV D 0; V A 0; V B 1.)
- Van Rensburg, H. J. (1952) Encroachment and control of shrubs in Africa in relation to grassland development, Sixth Inter. Grassland Cong., Proc., 6:585-591. (170: I 2; IV D 0; V B 2.)
- Van Rensburg, H. J. (1952) Grass burning experiment on the Msima River stock farm, Southern Highlands, Tanganyika, East Afr. Agric. Jour., 17:119-129. (173: I 2; II A 2; IV D 0,1; V C 1.)
- Vesey-Fitzgerald, D. F. (1963) Central African grasslands, Jour. of Ecol., 51:243-273. (173, 176: I 4; III G 0; IV D 2.)
- Watson, W. (1958) Tribal cohesion in a money economy, Manchester University Press, 246 pp. (176: I 2; IV D 0; V B 2.)
- Welch, J. R. (1960) Observations on deciduous woodland in the Eastern Province of Tanganyika. Jour. of Ecol., 48:557-574. (173: I 4; IV A 0,1; IV B 3; IV D 2.)
- West, O. (1958) Bush encroachment, veld burning and grazing management, Rhodesia Agric. Jour., 55. No. 4:407-425. (177: I 2; II A 2; II B 0; III C 1; III E 0,1,2,3; IV A 0; IV D 2; V B 1.)
- West, O. (1962) Factors affecting the carrying capacity of veld grazing, Interdepartmental Conference of Pasture Workers, Bulawayo. Federal Ministry of Agriculture, Rhodesia, n.p. (177: I 3; II A 2; III C 0; III D 2; III E 1; V B 2.)

- Westermann, Diedrich (1912) The Shilluk people, their language and folklore, Board of For. Miss. of the United Pres. Church of N. A., Philadelphia, 312 pp. (166: I 3; II A 2; III B 0; IV A 3.)
- Wilson, F. (1962) Making firebreaks in Ankole, East African Agric. and For. Jour., 27, No. 3:156-167. (174: I 2; II A 1; III B 0; IV D 1; V B 1.)
- Wilson, Godfrey (1938) The land rights of individuals among the Nyakyusa, Rhodes-Livingstone Papers, No. 1, Rhodes-Livingstone Institute, Livingstone, Zambia, 52 pp. (173: I 3; II A 2; V A 0; V B 2.)
- Wilson, J. G. (1962) The vegetation of the Karamoja District of the Northern Province of Uganda, Memoirs of Res. Div., No. 5, Uganda Dept. of Agriculture, 163 pp. (174: I 3; III E 0,1; III G 0; IV D 2)
- Wilson, Monica (1951) Good company: a study of Nyakyusa age villages, Oxford University Press, for the Int'l. African Institute, London, 278 pp. (173: I 4; II A 2; IV A 3; V B 2.)
- Young, R. S., and A. Golledge (1948) Composition of woodland soils and wood ash in Northern Rhodesia, Emp. Jour. of Exp. Agric., 16:76-78. (176: I 2; III B 0.)
- Zimmerman, Otto (1907/1908) Grass fires, Rhodesia Agric. Jour., 5:233-236. (177: I 2; II A 2; II B 0; III D 1,2; V B 4.)

Southern Africa

- Adamson, Robert Stephen (1938) The vegetation of South Africa, British Empire Vegetation Committee, London, 235 pp. (191: I 3; III E 3; IV D 2,3,3b; V A 0,3; V C 1.)
- Anonymous (1950) Autumn veld-burning experiment, Farmer's Weekly, 79. (191: I 3; III C 0,1.)
- Anonymous (1951) Good wattle yields from burnt plantations, Farmer's Weekly, 81. (191: I 3; III D 0.)
- Anonymous (1955) Herbage yields from seasonal burn experiments near Standerton. Frankenwald Field Research Station, Annual Report 1955. p. 10. (191: I 4; III E 0,1)
- Anonymous (1956) Veld burning, Farming So. Africa, 32, No. 5. (191: I 2; V B 1,2.)
- Baker, J. G. (1877) Flora of the Mauritius and Seychelles: a description of the flowering plants and ferns of those islands, L. Reeve & Co., London, 557 pp. (181: I 1; III B 0; III G 0; IV D 3b.)

- Basse, Elaine (1934) Les groupements végétaux du Sud-ouest de Madagascar, Ann. d. Sci. Nat., Dixième sér., botanique ... Tome XVI, Volume du centenaire, fasc. 2:94-229. (180: I 3; IV D 1.)
- Beard, J. S. and G. D. Darby (1951) An experiment on burning in wattle silviculture, J. So. Afr. For. Assoc., 20: 53-77. (190: I 4; III E 0,1; III G 0,1.)
- Board, C. (1962) The border region: natural environment and land use in the eastern Cape, Oxford University Press, Capetown, 238 pp. (191: I 2; IV A 2; IV D 1.)
- Botha, J. P. (1945) The burning of veld, Reprint from Farming So. Africa, Reprint No. 49, Government Printer, Pretoria, 6 pp. (repaged). (191: I 1; III B 0; V B 1,2.)
- Botha, J. P. (1945) Veld management in the Eastern Transvaal, Repr. from Farming So. Africa, Reprint No. 65, Government Printer, Pretoria, 5 pp. (repaged). (191: I 1; II A 2; III B 0; IV D 0; V B 1,2)
- Burchell, William J. (1953) Travels in the interior of southern Africa. Repr. from the original edition of 1822-1824 with some additional material and with an introduction by I. Schapera, The Batchworth Press, London. Vol. I, 381 pp., Vol. II, 371 pp. (190: I ?; III B 0; IV B 1; IV D 3b; V A 3.)
- Cardenau, J. (1898) De Fainarantsoa à Farafangana et à Fort-Dauphin (impressions de voyage; mai à décembre 1897), Colonie de Madagascar, Notes, reconnaissances et explorations, 4:1159-1174. (180: I 0; III B 0.)
- Coetzee, P. J. S. (1942) Fire and veld management. Veld-burning as an agent in the "ngongoni" sourveld, Farming So. Africa, 17:107-116. (191: I 1; III D 0; III G 0.)
- Cohen, C. (1950) The occurrence of fungi in soil after different burning and grazing treatments of the veld in the Transvaal, So. Afric. Jour. Sci., 46:245-246. (191: I 3; III D 3.)
- Cook, L. (1939) Grass burning, So. Afric. Jour. Sci., 36: 270-282. (191: I 2; III D 0; III E 0.)
- Coutts, J. R. H. (1945) Effect of veld burning on the base exchange capacity of a soil, So. Afric. Jour. Sci., 41: 218-224. (191: I 4; III D 1,2.)
- Daitz, J. (1953) A further report on the seasonal burn experiment at Bethal, University of Witwatersrand, Frankenwald Field Research Station, Annual Report 1953, pp. 33-34. (191: I 4; III D 0; III E 0.)
- Daitz, J. (1955) Available carbohydrate reserves in the roots of Themeda triandra from a seasonal burn experiment at Bethal, Frankenwald Field Research Station, Annual Report 1954, pp. 27-28. (191: I 4; III E 0,1.)

- Davidson, R. L. (1951) A long-term seasonal burn experiment near Standerton, Frankenwald Field Research Station, Annual Report 1951, pp. 47-55. (191: I 4; III E 0,1.)
- Davidson, R. L. (1951) Further analysis of a veld burning experiment at Bethal, Frankenwald Field Research Station, Annual Report 1951, pp. 39-46. (191: I 4; III E 0,1.)
- Davidson, R. L. (1952) Herbage yields from seasonal burn experiment at Bethal, Frankenwald Field Research Station, Annual Report 1952, pp. 32-33. (191: I 4; III E 0,1.)
- Davidson, R. L. (1952) Herbage yield from seasonal burn experiment near Standerton, Frankenwald Field Research Station, Annual Report 1952, pp. 30-31. (191: I 4; III E 0,1.)
- Davidson, R. L. (1953) Veld burning, a seasonal burn experiment in sour mixed brush veld, Frankenwald Field Research Station, Annual Report 1953, pp. 29-32. (191: I 4; III E 0,1.)
- Davidson, R. L. (1955) Further herbage yields from a seasonal burn experiment near Standerton, Frankenwald Field Research Station, Annual Report 1954, pp. 25-26. (191: I 4; III E 0,1.)
- D'ewes, Dudley (1960) "Three centuries of veld-fires." Jour. of the Bot. Soc. of So. Africa, 46:6-7. (191: I 1; III E 1; III G 0.)
- Grobbelaar, W. S. (1960) Controlled veld burning is essential. Farming So. Africa, 36, No. 8:46-48. (191: I 2; V C 1.)
- Harten, J. A. (1953) Beknopt overzicht van de landbouw der Bantus in de Unie van Zuid-Afrika en zijn problemen, Indonesië, 6, No. 4:317-329 (190: I 3; II A 0; V A 0, 3.)
- Humbert, Henri (1923) Les composées de Madagascar, Imprimerie E. Lanier. Caen, 337 pp. (180: I 3; III G 0; IV D 3b.)
- Humbert, Henri (1927) La destruction d'une flore insulaire par le feu: principaux aspects de la végétation a Madagascar. Mémoires de l'Académie Malgache, Fasc. V, 79 pp. (180: I 3; III G 0; IV D 0,1.)
- Humbert, Henri (1928) Végétation des hautes montagnes de Madagascar, in: Peuplement des hautes montagnes, Mém. Soc. Biogéogr. Paris, 2:195-220. (180: I 2; III E 0, 1.2; III G 0.)
- Jaeger, Fritz and Leo Waibel (1920) Beiträge zur Landeskunde von Südwestafrika. Mitteilungen aus den Deutschen Schutzgebieten... Ergänzungsheft Nr. 14, 80 pp. (190: I 3; III A 0; III B 0; III G 0; IV D 0.)

- Jeffreys, M. D. W. (1945) This burning question, Farm and Forest, 6:115-124. (191: I 1; III D 2; III E 0.)
- Karoo Region Veld Burning Investigation Committee (1961) Veld burning in the Karoo Mountains with special reference to sour grass veld areas, Farming So. Africa, 37, No. 5:36-37. (191: I 3; V B 2.)
- Keet, M. D. M. (1952) The veld and forest fire law of the Union of South Africa, Government Printer, Pretoria 18 pp. (191: I 4; V B 1.)
- King, J. A. (1957) Meteorological aspects of forest fire danger rating, J. So. Afr. For. Assoc., 29:31-38. (191: I 4; IV A 0,1,2; IV B 0,1,2.)
- Lebzelter, Viktor (1934) Eingeborenenkulturen in Südwest- und Süd Africa (Native cultures in S.W. and S. Africa), Hiersemann, Leipzig, Vol. II, 306 pp. (192: I 3; V B 2.)
- Liebenberg, L. C. C. (1934) Veld burning, Part I: How it affects the farmer as well as the country; Part II: Its influence on various types of vegetation, Farming So. Africa, 9. No. 99:213-215, No. 100:265-266. (190: I 2; II A 2. III G 0,1; III E 0,1.)
- Linton, Ralph (1933) The Tanala: a hill tribe of Madagascar, Field Museum of Natural History, Chicago, Anthropology Series, 22, 334 pp. (180: I 3; II A 2; IV D 2; V B 2.)
- Louvel, M. (1950) Notes sur les forêts malgaches de l'est, Rev. Inter. de Bot. Appl. et d'Agron. Tropicale, 30, No. 333-334:370-378. (180: I 3; IV D 2.)
- Marshall, John (1963) Man as a hunter, Natural Hist., 72: 291-309, 376-395. (193: I 1; II A 2; III A 0; IV D 0.)
- Marwick, B. A. (1940) The Swazi, Cambridge University Press, Cambridge, 320 pp. (195: I 2; V A 3; V B 2.)
- Morwood, G. E. (1951) The means, absolutes and frequencies of temperature and rainfall at Frankenwald, Frankenwald Field Research Station, Annual Report 1951, pp. 3-14. (191: I 4; IV A 0,1.)
- Pearson, C. H. O. (1952) The maintenance of organic matter in the soils of the Natal coastal belt, So. Afr. Sug. Jour., 36:17-23. (191: I 4; III D 0.)
- Penzhorn, K. E. W. (1942) Burning veld out of season, Farming So. Africa, 17:435-454. (191: I 2; III D 0; III E C; V B 1.)
- Perrier de la Bathie, H. (1927) Le Tsarantanana, l'Ankaratra et l'Andringitra, Mém. de l'Acad. Malgache, Fasc. III, Appendice II: Historique de la destruction de la végétation de la cime de Tsaratanana et ses conséquences, Tananarive, 71 pp. (180: I 2; II B 0; III B 0; III G 0; IV D 3b.)

- Phillips, John (1936) Fire in vegetation: a bad master, a good servant, and a national problem, Jour. of So. Afr. Botany, 2:35-45. (191: I 1; III E 0; V B 1.)
- Pienaar, A. F. (1959) Bush encroachment not controlled by veld burning alone, Farming So. Africa, 35, No. 9:16-17. (191: I 2; III E 0,1; III G 0,1.)
- Pons, J. E. (1955) Veld burning, Farming So. Africa, 30: 312-328. (190: I 2; IV B 1; IV D 1; V B 2.)
- Rycroft, H. B. (1947) A note of the immediate effects of veld burning on stormflow in a Jonkershoek stream catchment, J. So. Afr. Forestry Assoc., 15:80-88. (191: I 3; II A 2; III C 0,1; IV B 2.)
- Schapera, Isaac (1930) The Khoisan peoples of South Africa: Bushmen and Hottentots. Routledge, London, 450 pp. (190: I 3; II A 2; V B 2.)
- Scotney, D. M. (1964) Fire - a threat to our forests, Farming So. Africa, 39, No. 12:23-25. (191: I 1; II B 0; V B 2.)
- Scott, J. D. (1951) A contribution to the study of the problems of the Drakensberg Conservation Area, So. Afr. Dept. Agric. Sci., Bull., 324, 170 pp. (191: I 2; III D 0; III E 0; III G 0.)
- Service de l'Élevage de Madagascar (1949) Les feux de brousse à Madagascar, Bull. Agric. Congo Belge, 40:1945-1950. (180: I 2; II A 2; III E 0; V B 1.)
- Sherry, S. P. (1954) The effect of different methods of brushwood disposal upon site conditions in Wattle plantations, Part II: A study of runoff and erosion during the first two years after clear felling and regeneration, Natal U. Wattle Res. Inst. Report, 7:27-36. (191: I 4; III C 0,1,2; III D 2.)
- Sherry, S. P. (1960-1961) The effect of different methods of brushwood disposal upon site conditions in Wattle plantations, Part III: Runoff behavior over a nine year rotation. Natal U. Wattle Res. Inst. Report, 14:32-40. (191: I 4; III C 0,1,2; III D 2.)
- Sherry, S. P. (1964) The effect of different methods of brushwood disposal upon site conditions in Wattle plantations, Part IV: A study of runoff and erosion during the first two rainy seasons of the second crop cycle of the experiment, Natal U. Wattle Res. Inst. Report, 17: 41-50. (191: I 4; III C 0,1,2; III D 2.)
- Sherry, S. P. (1965) Personal communication, (191: I 4; II A 2; II B 0,1; IV A 2; IV B 0,1; IV D 3; V B 1,2.)

- Smit, I. B. J. (1953) Some notes on the effects of burning on two veld types at Frankenwald, Frankenwald Field Research Station. Annual Report 1953, p. 35. (191: I 4; III E 0,1.)
- South Africa, Republic of (1953-1961) Department of Forestry, Reports, 1953-1960, Government Printer, Pretoria, various pagings. (191: I 3; II B 0.3; V B 2.)
- South Africa, Republic of (1965) Personal communication (191: I 3; II A 0; II B 0.4; V B 1.)
- Steyn, D. C. (1940) The occurrence of poisonous plants on and trampling and burning of pasturage. Farming So. Africa, 15, No. 167:54,66. (191: I 1; III B 0; IV D 3b; V B 2.)
- Van Der Walt, J. L. (1961) Veld burning in the Neeuberg Range with special reference to the scrub veld. Farming So. Africa, 37, No. 5:33-35. (190: I 2; III 0,1; V B 2.)
- Vignal, P. (1956) La disparition de la forêt malagache des hauts plateaux. Bois et For. des Trop., 49:3-8. (180: I 3; II A 2; II B 2,5.)
- Vowinckel, E. (1958) Fire danger rating, Jour. So. Afr. For. Assoc., 31:58-73. (191: I 4; II B 3; IV A 0,2.)
- Watt, W. E. (1935) Forest protection from fire in South Africa, Government Printer, Pretoria. 13 pp. (191: I 4; V B 1.)
- Wellington, J. H. (1955) South Africa, Vol. I: Physical Geography, 568 pp., Vol. II: Economic and human Geography 283 pp., Cambridge University Press, Cambridge. (190: I 2; IV D 1.)

Latin America

- Barbour, W. (1942) Forest types of tropical America, Carib. For., 3:137-150. (200: I 3; IV D 0.)
- Beard, J. S. (1946) Los climas de vegetación en la América tropical, Rev. Fac. Nal. de Agronomía, 6:225-293. (200: I 4; IV D 2.)
- Beard, J. S. (1955) The classification of tropical American vegetation types, Ecology, 36:89-100. (200: I 4; IV D 1, 2.)
- Budowski, Gerardo (1958) The ecological status of fire in tropical American lowlands, Acta 33º Congreso Interamericano de Americanistas, San José, 1:264-278. (200: I 3; II B 0,3,5; III B 0; III E 3; III F 0,2; IV D 3b; V A 3.)
- Budowski, Gerardo (1964) Classification and origin of savannas in the light of a world vegetation classification, Inter-American Institute, Turrialba, Costa Rica, 8 pp. (mimeo.) (200: I 2; II A 2; IV D 0,3b.)

- Crist, Raymond E. (1964) Tropical subsistence agriculture in Latin America: some neglected aspects and implications, Smithsonian Institute, Washington, D.C. pp. 503-519. (200: I 2; V A 0,2,3; V B 2.)
- C. W. Thornthwaite Associates (1965) Average climatic water balance data of the continents Part VIII: South America, Publications in Climatology, 18(2):297-432, C.W. Thornthwaite Associates, Laboratory of Climatology, Elmer, New Jersey. (200: I 4; IV A 0,1.)
- Fuson, Robert H. (1963) The origin and nature of American savannas, Geographic Education Series No. 2, National Council for Geographic Education, Norman, Oklahoma, 34 pp. (200: I 3; II A 2; II B 0; III A 0,1,2; III B 0; III C 1; III D 0,1; III E 1; III G 0,1; IV A 0,1,2,4; IV B 0; IV C 0,1,2,3; IV D 1; V A 3.)
- Hills, Theo L. (1965) Savannas: a Review of a major research problem in a tropical geography, Canadian Geographer, 9:216-228. (200: I 3; III E 0,1,2; IV D 0,1,2; V A 3.)
- Hunter, J. Robert (1959) A new guide to land use planning in tropical areas, Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica, 30 pp. (mimeo.) (200: I 3; IV C 3; IV D 2.)
- Krochmal, A. (1961) How land burning ruins soil in Latin America, Org. Gard. and Farming, 8, No. 9:38-40. (200: I 1; III D 0.)
- Roseveare, G. M. (1948) The grasslands of Latin America, Imperial Bureau of Pastures and Field Crops, Bull. 36, 291 pp. (200: I 2; III G 0; IV A 0,1; IV C 0,3; IV D 0,1.)
- Smith, A. C. and I. M. Johnston (1945) A phytogeographic sketch of Latin America, in: Verdoorn, F., (ed.), Plants and plant science in Latin America, pp. 11-18. (200: I 2; IV D 1,2,3b.)
- Tortorelli, Lucas (1961) Los forestales en los programas de colonización en la America Latina, 10 pp. (mimeo.). (200: I 3; II B 1; III B 0; III D 2; III G 0.)
- Wernstedt, Frederick L. (1961) World climatic data, Latin America and the Caribbean, Department of Geography, Pennsylvania State University, 87 pp. (200: I 4; IV A 0,1.)

Middle America

- Allee, W. C. (1926) Measurement of environmental factors in the tropical rain-forest of Panama, Ecology 7:273-302. (227: I 3; IV A 0,1,2,3.)
- Allen, P. H. (1956) The rain forest of Golfo Dulce (Costa Rica), University of Florida Press, Gainesville, Florida, 417 pp (226: I 3; IV D 1.)
- Andrle, Robert F. (1964) Biogeographical study in southern Veracruz, Mexico, Ph.D. dissertation, Louisiana State University, pp. 75-178. (221: I 3; II A 1,2; II B 0,4; III D 2; III E 0,1; III G 1; IV A 0; IV D 0; V A 0,2,3; V B 0,1; V C 0,1.)
- Anonymous (1956) Fire protection. Rep. For. Dept. Brit. Hond. 1955, pp. 6-8. (228: I 3; II 0,1,2; III E 0,1; V B 1.)
- Anonymous (1944) Ventajas y desventajas de la quema de montaña, Revista de Agricult., San José, C.R., 16, No. 7: 269-270. (222: I 2; V B 1.)
- Bartlett, Harley H. (1936) A method of procedure for field work in tropical American phytogeography based upon a botanical reconnaissance in parts of British Honduras and the Peten forest of Guatemala, Botany of the Maya Area. Miscellaneous Papers. Carnegie Institution, Washington, D.C., n.p. (228: I 3; III F 2; IV D 1,2.)
- Blom, Frans and Oliver LaFarge (1927) Tribes and temples: a record of the expedition to Middle America conducted by the Tulane University in 1925, The Tulane University of Louisiana, New Orleans. 238 pp. (221: I 2; IV D 0,3b.)
- British Honduras (1962) Annual report of the Forest Department for the year 1961. Printing Department, Belize City, British Honduras. 18 pp. (mimeo.) (228: I 3; II A 0; II B 0,1; V A 2.)
- British Honduras (1963) Annual report of the Forest Department for the year 1962. Printing Department, Belize City, British Honduras. 12 pp. (mimeo.) (228: I 3; II A 0; II B 0,1; V A 2.)
- British Honduras (1964) Annual report of the Forest Department for the year 1963, Printing Department, Belize City, British Honduras, 10 pp. (mimeo.) (228: I 3; II A 0; II B 0,5.)
- Budowski, Gerardo (1962) Forest succession in tropical lowlands. Centro Tropical de Investigacion y Enseñanza para Graduados, Turrialba. Costa Rica, 3pp. (mimeo.) (226, 227: I 2; IV D 3b.)

- Budowski, Gerardo (1964) The classification of natural habitats in need of preservation in Central America, Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica. 19 pp. (mimeo.) (220: I 3; IV D 0.)
- Budowski, Gerardo (1964) Distribution of tropical American rain forest species in the light of successional processes, Inter-American Institute, Turrialba, Costa Rica, 5 pp. (mimeo.) (220: I 2; IV D 2.3b.)
- Carr, Archie (1953) High jungles and low, University of Florida Press, Gainesville. 226 pp. (224, 225: I 1; II A 2; II B 1.2; III B 0; IV D 0.)
- Coen, P. Elliott (1958) Climas de Costa Rica, Ciudad Un., San José, Costa Rica, 13 pp. (226: I 4; II A 2; IV A 0,1,2,3,4; IV B 0.1,2.)
- Conzemius, Edward (1932) Ethnographical survey of the Miskito and Sumu Indians of Honduras and Nicaragua, Bur. of Am. Ethnology, Bull. No 106. 191 pp. (224,225: I 1; II A 1,2; III E 1; V A 3; V B 2.)
- Cook, O. F. (1909) Vegetation affected by agriculture in Central America, U.S. Dept. Agric., Bur. Plant Industry, Bull. No. 145. Government Printing Office, Washington, D.C., 30 pp. (220: I 2; III G 0,1; IV D 3b; V B 0.)
- Cook, O. F. (1921) Milpa agriculture, a primitive tropical system, Ann. Report Smithsonian Institution for 1919, pp. 307-326. (220: I 3; III G 0,1; V A 3.)
- Cooke, C. Wythe (1931) Why the Mayan cities of the Peten District, Guatemala were abandoned, Jour. Wash. Acad. Sci., 21:283-287. (222: I 0; III B 0.)
- Corenjo, Francisco (1964) Personal communication. (227: I 3; II A 1; II B 0; III B 0.)
- Cosyns, J. (1939) Sur les feux de brousse au Guatemala, Inst. Roy. Colon. Belge, Bull. des Séances, 10:133-135. (222: I 1; II B 3; III B 0.)
- DeKalb, Courtenay (1893) Nicaragua: studies on the Mosquito Shore in 1892, Jour. Amer. Geog. Soc., 25:236-288. (225: I 0; V A 3.)
- Emerson, R. A. (1953) A preliminary survey of the milpa system of maize culture as practiced by the Maya Indians of the northern part of the Yucatan peninsula, Ann. Missouri Bot. Garden, 40:51-62. (221: I 2; II A 2; II B 4; III E 0; V B 2.)
- Esso Standard Oil, S.A., Ltda. Refineria Esso, Managua (1964) Personal communication. (225, 250: I 3; II A 0,1; III B 0.)

- Freeman, Peter (1963) Observations made on a field trip from Turrialba to San Isidro: ecology and land use. Inter-American Institute of Agricultural Sciences, Turrialba. Costa Rica, 7 pp., (mimeo.). (226: I 1; III G 0; IV B 0; IV C 3; IV D 0.1, 3b.)
- Galicia, D. F. (1951) Manual de prevencion y extincion de incendios forestales para uso de las escuelas del estado de Chihuahua, Mexico, Asociacion Nacional de Productores de Maderas de Pino, 19 pp. (221: I 1; II B 0; III E 0.1; III G 0; V B 1.)
- Higbee, E. C. (1948) Agriculture in the Maya homeland, Geog. Rev., 38:457-464. (221: I 2; IV D 3; V C 0.)
- Holdridge, Leslie R. (1961) Pasture lands in Central America and Panama, Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica 4 pp. (mimeo.). (220: I 1; IV D 0.1, 2.)
- Holdridge, L. R. (1957) The vegetation of mainland Middle America. National Research Council of the Philippines, University of the Philippines, Diliman. Quezon City, 12 pp. (mimeo.) Repr. from Proceedings of the Eighth Pacific Science Congress, 1957. 4:148-161. (220: I 2; IV D 0.1, 2.)
- Izquierdo, Jorge Eduardo (1964) Las fotografías aéreas en la estimación del volumen de bosques secundarios en el trópico, Turrialba. 14, No. 1:39-41. (226: I 4; IV D 0.)
- Johannessen, Carl (1963) Savannas of interior Honduras, Ibero-Americana. 46:1-173. (224: I 2; III A 0; III E 0.1; III G 0; IV D 0.3b; V A 2; V B 2.)
- Johannessen, Carl (1959) The geography of the savannas of interior Honduras. Ph.D. Dissertation, University of California, 283 pp. (224: I 2; III A 0; III E 0; III G 0; IV D 0.3b; V A 2; V B 2.)
- Kenoyer, L. A. (1929) General and successional ecology of the lower tropical rain forest at Barro Colorado Island, Panama, Ecology. 10:201-222 (227: I 2; IV D 1, 3b.)
- Lundell, Cyrus Longworth (1937) The vegetation of Peten, Carnegie Institution of Washington, Washington, D. C., 224 p. (222: I 2; III G 0; IV A 0; IV D 0; V A 3; V B 1.)
- McBride, G. McC. and Merle A. McBride (1942) Highland Guatemala and its Maya communities. Geog. Rev., 32:252-268. (222: I 0; V A 3; V B 1.)
- Martin, P. D. (1953) Vegetation of the Gomez Farias region, northern limit of humid tropical forests in eastern Mexico, Bull. Ecol. Soc. Amer., 34:92-93. (221: I 2; IV D 0.)

- Mejorada, Norberto Sanchez (1959) Conifers of Mexico, Unasylva, 13, No 1:24-35 (221: I 2; III E 0,3; III G 0; V B 2.)
- Mirandar, Luis E. (1964) Personal communication, (225, 250: I 4; II A 0,1; II B 0; III B 0; V B 1.)
- Parsons, James (1955) The miskito pine savanna of Nicaragua and Honduras, Annals. A.A.G., 45:36-63. (224, 225: I 2; IV A 0,2; IV B 0; IV C 3; IV D 3b.)
- Pearson, Ross (1963) Zones of agricultural development in Guatemala: an experiment in land reform, Jour. of Geog., 62, No. 1:11-22. (222: I 1; II A 2; V A 3; V B 2; V C 1)
- Popenoe, Hugh (1960) Effects of shifting cultivation on natural soil constituents in Central America. Ph.D. dissertation, University of Florida, Gainesville, 165 pp. (220: I 4; III D 0,1,2; III E 0; III G 0,1.)
- Popenoe, Hugh (1964) Personal communication. (222: I 2; III G 0; IV D 0.)
- Popenoe, Hugh (1960) Some soil cation relationships in an area of shifting cultivation in the humid tropics, Seventh Intern. Congress of Soil Science, Madison, Wisconsin, Reprint Transactions, Vol. II, 9 pp. (222: I 4; IV C 2.)
- Popenoe, Hugh (1959) The influence of the shifting cultivation cycle on soil properties in Central America, Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association, 1957, 7:72-77. (220: I 4; II A 0; III D 0,1,2,3; IV A 0; IV C 0,1; IV D 0; V A 3; V B 2)
- Portig, H. W. (1965) Central American rainfall, Geog. Rev., 55, No. 1:68-90. (220: I 4; II A 2; IV A 0,2,3,4; IV B 0,2.)
- Rawitscher, F (1946) Die Erschöpfung tropischer Boden infolge die Entwaldung, Acta Tropica (Basel), 3:211-247 (224,225: I 3; III D 0; III G 0.)
- Romney, D. H. , (ed.) (1959) Land in British Honduras: report of the land use survey team, Colonial Office, Colonial Res. Publs. No 24, London, n.p. (228: I 2; IV C 3; IV D 0.)
- Skutch, A. F (1950) Problems in milpa agriculture, Turrialba, 1:4-6. (226: I 1; II A 1; V B 2.)
- Stein, A. H (1960) Costa Rica and its forests, Summary, Inter-American Institute, Turrialba, Costa Rica, 18 pp. (mimeo.) (226: I 3; II B 0,1,3; III G 0,1; IV A 3; IV C 0,3; IV D 1; V A 3.)

- Stone, Doris Z. (1949) The Boruca of Costa Rica, Papers of the Peabody Museum of Amer. Archeol. and Ethnol., Harvard University, 26, No. 2, 60 pp. (226: I 3; V B 2.)
- Stone, Doris (1962) The Talamancan tribes of Costa Rica, Papers of the Peabody Museum of Amer. Archeol. and Ethnol., Harvard University, 43, No. 2:108 pp. (226: I 1; IV A 0; V A 0; V B 2, V C 1.)
- Stout, David B. (1947) San Blas Cuna acculturation: an introduction, Viking Fund Publications in Anthropology, No 9, 124 pp. (227: I 3; II A 2; II B 1; V B 2.)
- Taylor, B. W. (1963) An outline of the vegetation of Nicaragua, Jour. of Ecol., 51:27-54. (225: I 4; II A 2; II B 3; IV D 0.)
- Taylor, B. W. (1962) The status and development of the Nicaraguan Pine savannas. Carib. For., 23:21-26. (225: I 2; III G 0; V B 1.)
- Uranga L. A. (1950) Servicio de prevencion y combate de incendios, Memoria de la IV Convención Nacional de Maderas de Pino, 1950, Chihuahua, Chila., 4:104. (221: I 0; V B 1.)
- Valenzuela, C. J. L. (1958-1959) El efecto de las quemadas sobre el suelo, Suelo Tico, 11, No. 41:1-22. (226: I 4; III D 0.1,2,3.)
- Verduzco Gutierrez, J. and G. Gaitan Medina (1963) Causes and control of forest fires, (in Sp.). Mex. Agric 10, No 117:21-31. (221: I 2; IV B 2.)
- Vogt, William (1946) The population of El Salvador and its natural resources. Pan American Union, Washington, D. C. 30 pp. (223: I 3; III G 0.1.)
- Wise, Harry (1965) Personal communication. (224: I 3; II A 2; II B 0.3; III A 0.3; III B 0; III C 1; III F 0,2; IV B 0; IV D 1; IV E 1.)

Insular Caribbean and Bahamas

- Beard, John Stewart (1946) The natural vegetation of Trinidad. Oxford Forestry Memoirs, No 20, Clarendon Press, Oxford. 152 pp. (235: I 3; III E 3; IV A 0; IV C 2; IV D 1.3b.)
- Beard, John Stewart (1949) The natural vegetation of the Windward and Leeward islands. Oxford Forestry Memoirs, No. 21, Clarendon Press, Oxford. 192 pp. (236: I 2; III B 0; IV D 0.)

- Seard, J. S. (1953) The savanna vegetation of northern tropical America. Ecol. Monographs, 23:148-215. (229: I 1: III B 0; IV A 3; IV D 0, 3b; V B 2.)
- Brooks, R. L. (1943) Extracts from memorandum on vegetation fires. Appendix C. 87-89. in: Wakefield, A. J. et al. Report of the Agricultural Policy Committee of Trinidad and Tobago. Government Printer, Rhodes, Part I: 142 pp. Part II: 56 pp. (235: I 1: III B 0; V A 3; V B 1.)
- Budowski, Gerardo (1957) Recent trends in tropical American forestry. Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica. 2 pp. (mimeo.). (235: I 1; III E 0,1; V A 3; V B 3.)
- Cornille, F. (1951) Le problème des incendies de forêts en Haïti. Bull. Agr. 1. No. 10:1-4. (231: I 1: II B 0; V C 1.)
- Durland, William D. (1922) The forests of the Dominican Republic. Geog. Rev. 12. No. 2:206-222. (232: I 2; IV A 0,1; IV D 1.)
- Espinal, Agustín (1964) Personal communication. (232: I 3; II B 0; III D 0,1; III E 1,2; V A 3; V B 1,3.)
- Fanshawe, D. B. (1954) Forest types of British Guiana, Carib. For. 15:73-111. (237: I 4; IV D 2.)
- Greig-Smith, P. (1952) Ecological observations on a degraded and secondary forest in Trinidad, B.W.I. Jour. of Ecol., 40:283-330. (235: I 4; IV C 3; IV D 2.)
- Hodge, W. H. (1943) The vegetation of Dominica. Geog. Rev., 33:349-375. (232: I 3; IV D 2.)
- Hodges, Walter H. and Douglas Macrae Taylor (1957) The ethnobotany of the island Caribs of Dominica, Webbia. 12. No. 2:513-644. (237: I 0; V B 2.)
- Holdridge, L. R. (1947) The pine forest and adjacent mountain vegetation of Haiti considered from the standpoint of a new climatic classification of plant formations, Ph.D. dissertation. University of Michigan, Ann Arbor, Michigan. 186 pp. (231: I 3; III B 0; IV D 2.3b.)
- Holdridge, L. R. (1942) The pine forests of Haiti, Carib. For. 4:16-22. (231: I 3; II B 0; V B 1,3.)
- Jervis, Roy N. (1953) A botanist's glimpse of the Gran Piedra region of Cuba, Asa Gray Bulletin. N. S.. 2:43-50. (230: I 3; III G 0; IV D 0.)

- Kalkkinen, Eero (1960) Forestry progress in Latin America, Fifth World Forestry Cong. 1960, Proc., 1:229-232. (200: I 1; V C 1.)
- Lovell, A. R. (1960) The vegetation of Antigua, West Indies, Jour. of Ecol., 48:495-527. (237: I 4; IV A 0,1; IV D 2.)
- Marshall, R. C. (1934) The physiography and vegetation of Trinidad and Tobago, Oxford Forestry Memoirs, No. 17, Clarendon Press, Oxford, 56 pp. (235: I 2; III B 0; III G 0; IV D 3b.)
- Nicholls, H. A. A. (1901) The harmfulness of bush fires in the West Indies, Ind. For. 27, No. 1:384-394. (229: I 2; IV C 2,3; V B 2.)
- Richardson, W. D. (1963) Observations on the vegetation and ecology of the Aripo savannas, Trinidad, Jour. of Ecol., 51:295-314. (235: I 4; IV D 2.)
- Ross, Philip (1961) The plant ecology of the teak plantations on Trinidad, Ecology, 42:387-398. (235: I 4; III E 0; IV A 0,1; IV D 2.)
- Stehlé, H. (1925) Forest types of the Caribbean Islands, Carib. For., 6, supplement, pp. 271-414. (229: I 4; IV A 0,1; IV C 3; IV D 2.)

South America

- Aitken, W. Ernest (1964) Personal communication. (250, 261: I 2; II A 0,2; II B 3; II C 0,4; III C 1; IV C 2; V A 6.)
- Anonymous (1963) Simposio Sobre o Cerrado, Ed. de Universidade de São Paulo, São Paulo, 424 pp. (241: I 2; IV A 0,1,2,3,4; IV D 0,1,2; V A 3; V B 2,3.)
- Arens, K. O. (1958) O cerrado como vegetação oligotrófica, Faculdade de Filosofia, Ciências e Letras Universidade de São Paulo, Boletim, No. 15, São Paulo, pp. 59-77. (241: I 2; III G 0; IV D 1,2.)
- Arnold, Kieth, (1964) Personal communication, (255: I 3, II C 1,4; III B 0; III E 0; III G 0.)
- Arrieta P., Oscar (1965) Personal communication. (261: I 2; II A 2; II B 0, II B 1.)
- Aschmann, Homer (1955-56) Hillside farms, valley ranches: land-clearing costs and settlement patterns in South America, Landscape, 5, No. 2:17-24. (240: I 1; II B 1; IV C 3; V A 3.)
- Baldanzi, Giampiero (1959) Efeito da queimada sobre a fertilidade do solo, Boletim Técnico do Depto. de Prod. Vegetal., Secretaria de Agr. do Paraná, No. 1, 56 pp. (241: I 4; III D 0,1,2,3.)

- Baldanzi, G. (1959) Il fuoco come instrumento nell'agricoltura dei paesi intertropicali, World Cong. Agr. Res., Proc., 1189-1193, 1194-1197. (241: I 2; V A 3; V B 2.)
- Baldanzi, G. (1960) Il fuoco come instrumento nell'agricoltura dei paesi intertropicali, Rev. di Agr. Subtrop. e Trop., 54, No. 10-12:792-798. (241: I 4; III D 0.)
- Baldanzi, G. (1961) Novos resultados en relocao ao problema da queima, Pelotas. Inst. Agron. do Sul, B. Téc. No 32, 12 pp. (241: I 4; III D 0.)
- Barros, W. D. de (1945) E necessario conservar o solo, Brazil. Min. da Agro., Bull., 34, No. 6:31-36, No. 8: 21-25 (241: I 2; III D 0,1,2.)
- Bates, Henry Walter (1864) The naturalist on the River Amazons. . . John Murray, London, 466 pp. (241: I 2; IV D 0; V A 0,3.)
- Bates, M. (1948) Climate and vegetation in the Villaviciencio region of eastern Colombia, Geog. Rev., 38:555-574. (250: I 2; III E 3; V A 3.)
- Beard, J. S. (1949) Brazilian campo cerrado: fire climax or edaphic climax, Geog. Rev., 39:664-666. (241: I 2; II A 2; III A 0, III B 0; III D 0,1,2; III E 0,1,2; III G 0;
- Beard, J. S. (1944) Climax vegetation in tropical America, Ecology, 25:127-158. (240: I 4; IV D 2.)
- Beard, J. S. (1952) The vegetation of British Guiana - a preliminary review. Empire Forestry Rev., 31:336-337. (251: I 3; III E 3; IV A 0; IV C 3.)
- Benoist, R. (1926) La végétation de la Guiane française, Comptes Rendu Sommaire des Séances de la Société de Biogéographie. Troisième année. 22:49-51. (253: I 1; II A 2; IV D 0 1.)
- Birbragher, Leon. and Isaac Sredni. (1965) Personal communication (250: I 0; II A 1; II B 0,1,2,3,4,5; III A 3.)
- Bottenburg, M. Van (1952) The forest situation in Colombia, Unasylva, 6:65-70. (250: I 0; V A 3; V C 1.)
- Bouillene, R. (1924, 1925) Savanes équatoriales du Bas-Amazone, Compte Rendu Sommaire des Séances de la Société de Biogéographie, Première et deuxième années, 5:31, 32 8:51, 52 (240: I 2; IV D 0.)
- Bouillenne, Ray (1926) Savanes équatoriales en Amérique du Sud. Bull. Soc. Roy. de Bot. de Belg. 2, No. 58: 217-223 (241: I 2; IV A 0; IV C 3; IV D 1.)
- Braun Eitel, H. G. (1962) The soils of Brazil and their possibilities for agricultural use, Rev. Bras. Geog. 24:43-78 (241: I 4; IV C 3.)

- Braun, O. (1956) Classificacion de los bosques de Bolivia, Bol. For. Serv. For. Bolivia, 1:73-78. (262: I 2; IV D 1.)
- Budowski, G. (1951) Los incendios forestales en Venezuela, Agr. Venezol., 16, No. 155:24-28. (255: I 2; III C 0, 2,3; III D 0; III E 0,1; III G 0,1.)
- Cabada, J. M. de la and J. Antonio Rugeles, (1954) Eliminemos las quemas: como eliminar la practica de las quemas in nuestra agricultura, Agr. Venezol., 9, No. 109,110:4-9. (255: I 1; III G 0,1; V B 1.)
- Camargo, Felisberto C. (1958) Report on the Amazon Region, Problems of the Humid Tropics, Humid Tropics Research, UNESCO, pp. 11-24. (241: I 3; IV D 1; V A 0.)
- Camero.Zamorra, J. (1952) Quemass e incendios forestales, Agr. Venezol., 17, No. 158:39-42. (255: I 1; III G 0; V B 1.)
- Campbell, R. S. (1960) Use of fire in grassland management, Prepared for F.A.O. First Working Party on Pasture and Fodder Development in Tropical America, Maracay, Venezuela 10 pp. (255: I 2; II A 2; III B 0,1; III C 0; III G 0; V B 0,1.)
- Campos, Gonzaga de (1911) Mappa florestal, in: [Brazil] Ministerio da Agricultura, Industria e Commercio, Relatorio Apresentado ao Presidente da Republica dos Estados Unidos do Brazil pelo... Dr. Pedro de Toledo, Vol. III, pp. 1-98. Directorio Geral de Estadistica, Rio de Janeiro, (241: I 2; IV D 3b.)
- Cardoso, Joao P. (1911) Tetatorio da exploracao do littoral de S. Sebastiao e do Rio Juqueryquere e seus afluentes, in: Exploracao do Rio Jiqueryquere Sao Paulo, Comissao Geographica e Geologica do Estado de S. Paulo. 19 pp (241: I 0; IV D 3b.)
- Caspar, Franz (1952) Tupari: unter Indies im Urwald Brasiliens. F. Vieweg & Sohn, Braunschweig, 217 pp. (241: I 1; II A 1; II B 2; III A 0; IV D 0.)
- Castellanos, Alberto (1938) Algunas formaciones caracteristicas de la vegetacion Argentina, Anais de Primeira Reuniao Sul-Americana de Botanica, 3:383-388. Ministerio da Agricultura Jardim Botanico do Rio de Janeiro, Rio de Janeiro. (264: I 1; IV D 0.)
- Castro Soares, Lucio de (1948) Delimitacao da Amazonia para fins de planejamento economico, Rev. Bras. Geog. 10:163-211. (241: I 1; V A 3.)
- Chacon, Senor Rene Prieto, (1965) Personal communication. (262: I 2; IV D 1.)

- Chevalier, Aug. (1928) Sur l'origine des campos brésiliens et sur le rôle des Imperata dans la substitution des savanes aux forêts tropicales. C.R. Ac. Sci., 187, No. 22:997-999. (241: I 2; IV D 3b.)
- Cianciulli, P. L. (1963) Incêndios florestais do Paraná, dura lição para o Brasil, A Rural, 43, No. 511:12-13. (240: I 0; IV D 3b; V C 1)
- Venezuela (1955) El problema de los incendios en Venezuela, Comision Forestal Latinoamericana, Delegation Venezuela, Agr. Venezol., 20, No. 183:16-19, 52. (255: I 2; II B 0; III B 0; III C 1; III D 0,1,2,3; V B 1.)
- Cook, O. F. (1916) Agriculture and native vegetation in Peru, Jour. Wash. Acad. Sci., 6:284-293. (261: I 0; II B 2; III B 0.)
- Crist, Raymond E. (1944) Brazilian journey, Bull. Pan. Am. Union, 78:Oct. and Nov., 1944, Repaged separate, 16 pp. (241: I 1; III B 0; IV D 0.)
- Crist, Raymond E. (1943) Cattle ranching in the tropical rain forest, Sci. Monthly, 56:521-527. (255: I 1; V C 1.)
- Crist, Raymond E. (1952) The Cauca Valley, Colombia: land tenure and land use, University of Florida, Gainesville, Florida. 118 pp. (250: I 1; III B 0; V C 1.)
- C. Z. J. (1952) Quemas e incendios forestales, Agr. Venezol., 17, No. 158:39-43. (255: I 1; II B 0; V B 1.)
- Dampier, William (1697) A new voyage round the world... illustrated with particular maps and draughts, James Knapton. London 550 pp. (250: I 2; II B 0; IV D 0,1; V A 3.)
- Dansereau, Pierre (1948) The distribution and structure of Brazilian forests, Bull. du Service de Biogéographie, No. 3. University of Montreal, Montreal, 17 pp. Reprint from: Forestry Chronicle. 23:261-277. (1947). (241: I 3; III G 0,1; IV D 1,2)
- Dansereau, Pierre (1950) Ecological problems of southeastern Brazil, Sci. Monthly, 71, No. 2:71-84. (241: I 3; II B 5; III G 0; IV D 3b.)
- Decker, S. (1929) Burning and its harmful effects on tropical soils, (in Port.), Bol. Agric. S. Paulo, 31 pp. (241: I 4; III D 0,1,2,3; III E 0.)
- Denevan, William (1965) The campo cerrado vegetation of Brazil, Geog. Rev., 55, No. 1:112-115. (241: I 2; III B 0; III G 0; IV D 0.)

- Dobrizhoffer, Martin (1784) Historia de Abiponibus, equestri bellicosaque Paraquariae natione, typis Josephi nob. de Durzbek, Vienna, Vol. I, 476 pp., Vol. II, 499 pp., Vol. III, 424 pp. [Eng. trans. 1822 - An account of the Abipones, an equestrian people of Paraguay, John Murray, London, Vol. I, 435 pp., Vol. II, 446 pp., Vol. III, 419 pp.] (263: I 0; V A 1,3.)
- Dugan, A. (1945) On the vegetation and plant resources of Colombia, in: Verdoorn, Fr., Plants and Plant Science in Latin America, Waltham, Mass., Chronica Botanica Co., pp. 417-418. (250: I 3; III B 0; IV A 0; IV D 3b.)
- Eden, M. J. (1964) The savanna ecosystem - Northern Rupununi, British Guiana, McGill University Savanna Research Project, Savanna Research Series No. 1, McGill University, Dept. of Geography, Montreal, 216 pp. (251: I 4; II A 2; III E 1,2,3,4; III G 1,2; IV A 0,1,2,3,4; IV C 0,1,2,3; IV D 1; V A 0,1,2,3; V B 0,1,2,3,4; V C 0,1.)
- Evans, Clifford and Betty J. Meggers (1955) Life among the Wai Wai Indians, Nat. Geog. Mag., 107. No. 3:329-346. (251: I 1; II B 2; III A 0.)
- Fanshawe, D. B. (1952) The vegetation of British Guiana: a preliminary review, Imp. For. Inst. Paper No. 29, Oxford, 96 pp. (251: I 4; IV D 2.)
- Ferri, Mario G. (1961) Aspects of the soil-water plant relationship in connection with some Brazilian types of vegetation. Tropical Soils and Vegetation, Abidjan Symposium 1959, UNESCO. pp. 103-109. (241: I 4; IV C 2,3; IV D 2.)
- Freise, F. W. (1939) Investigations on the effects of burning debris in tropical soils, observations in coastal virgin forests of Brazil. Tropenpflanzer, 42:1-22. (241: I 4; III B 0.)
- Freise, F. (1938) The drought region of northeast Brazil, Geog. Rev., 28:363-379. (241: I 2; IV A 0,1; IV D 1,3.)
- Froés Abreu, Sylvio (1931) Na terra das palmeiras, Estudos brasileiros, Rio de Janeiro. (241: I 3; IV D 1,2.)
- Gillin, John (1936) The Barama River Caribs of British Guiana, Papers of the Peabody Museum of Amer. Archeol. and Ethnol., Harvard Univ., 274 pp. (251: I 3; V B 0,1,2.)
- Gonzalez, Silva, J. M. (1957) Los incendios de Brazil y Venezuela, Agr. Venezol., 21, No. 193:22-23. (241: I 0; V B 1,2.)
- Gonzalez Medici, E. (1957) La guardia nacional en la prevencion y extincion de incendios forestales, Agr. Venezol., 21, No. 193:16-21. (255: I 1; II B 0.)

- Gordon, B. LeRoy (1957) Human geography and ecology in the Sinu country of Colombia. Ibero-Americana. 39, University of California Press. Berkeley and Los Angeles, 136 pp. (250: I 4; II A 2; III B 0; III E 0,1,2; III G 0; IV D 0,1,2; V A 0,3; V B 1,3,4.)
- Guevara, J. M. (1964) Personal communication. (255: I 1; II A 2; II B 0; III E 0; V B 3.)
- Gutierrez de Pineda, Virginia (1948) Organizacion social en la Guajire. Revista del Instituto Etnologico Nacional (Bogota), 3, No 2:1-255 (250: I 3; V A 2.)
- Hardy, F. (1960) Edaphic savannas in tropical America, (with particular reference to those caused by nutrient deficiency). Instituto Inter-Americano de Cifricias Agricolas, Turrialba, Costa Rica. 20 pp. (mimeo.). (251, 241, 235: I 4; II B 3; III G 0; IV A 0,3; IV C 2,3; IV D 0,1,3b.)
- Hardy, F. (1960) Fertilizer problems in the campo cerrado of east central Brazil. Instituto Interamericano de Cieucias Agricolas, Turrialba, Costa Rica, 7 pp. (mimeogr.). (241: I 4; II A 1; IV C 2; IV D 3b.)
- Heinsdijk, Dammis (1960) Surveys applicable to extensive forest areas in South America, Fifth World Forestry Cong., 1960 Proc., 1:251-257. (241: I 3; IV D 1,2.)
- Herskovits, Melville J. and Frances S. Herskovits (1934) Rebel destiny: among the Bush Negroes of Dutch Guiana, McGraw Hill. New York, 366 pp. (252: I 3; V B 0.)
- Hickey, M. J., (1964) Personal communication. (250: I 3; II A 1; II B 0; III A 0; III B 0; III G 0.)
- Hills, Theo L., (1964) McGill University Savanna Research Project. Progress Report, March, 1964, McGill University Montreal, 26 pp. (251: I 3; III G 0,1; IV C 3; IV D 1; V A C,2,3; V B 0.)
- Hillis, Theo L. (1961) The Interior of British Guiana and the myth of El Dorado. Canadian Geographer, 5, No. 2: 30-43. (251: I 3; III C 0,2; III D 0,1; III E 0,2; IV A 0,1; IV C 0,1,2,3; IV D 0,1,2; V A 0,3; V B 2,3.)
- Hochreutiner, Benedict Pierre Georges (1929) Die paraguayische Pflanzenwelt, in: Schuster, Adolf N., Paraguay: Land, Volk, Geschichte Wirtschaftsleben und Kolonisation, pp. 91-119. Strecker und Schröder, Stuttgart, 667 pp. (263: I 2; II B 0; III B 0; III G 0; IV D 0)
- Hoehne, Federico Carlos (1937) Botânica e Agricultura no Brasil no Seculo XVI (pesquisas e Contribuicoes), Companhia Editora Nacional, Sao Paulo, 410 pp. (241: I 3; V B 2.)

- Hoehne, Federico Carlos (1910) Commissao de Linhas Telegraphicas e Estrategicas de Matto Grosso ao Amazonas, Anexo no. 5, Historia Natural. Botanica. Parte 1. Introduccoa, pp. 5-11, Rio de Janeiro. (241: I 1; II A 2; III E 0; III G 0.)
- Holmberg, Allan R. (1950) Nomads of the long bow: the Siriono of eastern Bolivia, Institute of Eco. Anthropol. Pub. No. 10, Smithsonian Institute, Washington, D. C., 104 pp. (262: I 3; IV C 3; V A 3; V B 2.)
- Horn, E. F. (1945) Forest resources and forest types of the province of El Oro. Carib. For., 6:209-217. (260: I 1; IV A 0,1; IV C 3; IV D 1.)
- Horn, E. F. (1947) The grasslands, savanna forests and dry forests of Brazil. Carib. For., 8:134-144. (241: I 3; IV D 1.)
- Hueck, K. (1960) Map of the vegetation of the Republic of Venezuela, (in Sp.), Inst. Forest. Latinoamer. de Invest. y Capacitacion, B., 7:3-15. (255: I 3; IV D 1.)
- James, Preston E. (1953) Land use in northeastern Brazil, Annals, A.A.G. 43:98-126. (241: I 2; III G 0; V A 3.)
- James, Preston E. (1953) Trends in Brazilian agricultural development. Geog. Rev. 43, No 3:301-328. (241: I 1; V A 3; V B 2; V C 1.)
- Koch-Grünberg, Theodore (1906) Bericht über seine Reisen am oberen Rio Negro und Yapura in den Jahren 1903-1905. Zeitschr. d. Gesellsch. F. Erdkunde zu Berlin, 1906, No. 2:80-101. (241, 250: I 2; III G 0,1; IV D 0.)
- Koch-Grünberg, Theodore (1910) Zwei Jahre unter den Indianern: Reisen in Nordwest-Brasilien 1903/1905. 2 vols., Strecker und Schroeder, Stuttgart. (241: III G 0,1; IV D 3b.)
- Krause, Annemarie (1952) Mennonite settlement in the Paraguayan Chaco. Ph.D. dissertation, University of Chicago, Chicago. (263: I 2; II B 5; III G 0,1.)
- Krause, Annemarie (1965) Personal communication. (263: I 2; II B 5; III G 0.)
- Lanjoun, J. (1954) The vegetation and the origin of the Surinam savannas. VIII Congr. Internat. de Bot., 1954, Paris, 7-8:45-48. (252: I 2; III E 1; IV D 1.)
- Leeds, Anthony (1961) Yaruro incipient tropical forest horticulture: possibilities and limits, in: Wilbert, J (ed.) The evolution of horticultural systems in native South America: causes and consequences Antropologica, Supp. No. 2:13-46. (255: I 4; II B 1; III D 1; III E 0; IV B 0; IV C 0,3; V A 0; V B 2,3.)

- Leonard, Olen E. (1948) Santa Cruz: a socioeconomic study of an area in Bolivia, U.S. Dept. of Agric., Office of Foreign Agricultural Relations, Foreign Agric. Report, No. 31. Washington, D.C., 71 pp. (262: I 3; II A 2; IV C 0; V A 3; V B 0.)
- Levi-Strauss, Claude (1948) The Nambicuara, Bur. of Am. Ethnology, Bull., 143. No. 3:361-369. (241: I 3; V A 3; V B 3.)
- Lima, R. Rodrigues (1958) Aspectos fisiograficos da regio Amazonica. An. Bras. Econ. Flor., Inst. Nac. Pinho 10:307-317. (241: I 1; IV D 1.)
- Lindeman, J. C. and S. P. Moolenaar (1955) Voorlopig overzicht van de bostypen in het noordelijk deel van Suriname, Dienst's Lands Bosbeheer. Paramaribo, 55 pp. (252: I 2; IV D 1.)
- Lisbola, J. M. B. (1956) Ofogo - grande fantasma, Minas Gerais, Dept. de Prod. Veg., B. de Agr., 5, No. 9-10: 33-41. (241: I 3; II B 0,3.)
- Löfgren, Alberto (1898) Ensaio para una distribuição vegetaes nos diversos grupos floristicos no estado de Sao Paulo. Boletim da Comissão Geographica e Geologica de São Paulo. No. 11, 50 pp. (241: I 1; IV D 3b.)
- McClung, A. C. and De Freitas, L. M. N. (1959) Sulfur deficiency in soils from Brazilian campos, Ecology, 40, No. 2:315-317. (241: I 4; III B 0.)
- Martius, C. F. P. (1840-1865) Flora Brasiliensis. Enumeratio Plantarum in Brasilia hactenus detectarum... Argumentum Fasciculorum I-XL. Lipsiae apud Frid. Fleischer in Comm. (241: I 1; II B 3; III B 0; IV D 3b; V B 0.)
- McGill University (1962-63) Climatic observations No. 1, St. Ignatius, Rupununi District, British Guiana, McGill University, Montreal. Savanna Research Project, n.p. (251: I 4; IV A 0.)
- Murphy, Robert (1954) The rubber trade and the Mundurucu village, Ph.D. dissertation, Columbia University, (241: I 2; II A 2; V B 0.2.)
- Myers, J. G. (1936) Savannah and forest vegetation of the interior Guiana plateau, Jour. of Ecol. 24:162-184. (251, 252, 253: I 3; III G 0; IV D 1.)
- Nimuendaju, Curt (1952) The Tukuna, University of California Publications in American Archeology and Ethnology, 45:1-210. (241: I 2; V B 0.)
- Peixoto, A. R. (1957) As queimadas e a diminuição das safras. Bahia. Inst. Bahiano do Fumo, B. Mins. de Inform. 6, No. 7:1-3. Also: Anu. Bras. de Econ. Florestal, 10, No. 10:257-258. (241: I 1, III D 0, 1,2,3.)

- Myers, J. G. (1933) Notes on the vegetation of the Venezuelan llanos, Jour. of Ecol., 21:335-349. (255: I 4; IV A 0,1; IV C 2,3; IV D 1; V A 3.)
- Perez, E. (1959) Importancia de las ligas contra incendios, Agr. Venezol., 23, No. 215:17. (255: I 1; V B 1.)
- Petriceks, Janis (1955) The present state of forest exploitation in Venezuela, Empire Forestry Rev., 34, No. 1:64-67. (255: I 1; IV D 1.)
- Pineda Giraldo, Roberto (1947) Aspectos de la Magia en la Guajira, Revista del Instituto Etnologico Nacional (Bogota), Vol. 3:1-164. (250: I 3; II A 2; IV A 0; IV D 3.)
- Pitt, G. J. W. (1961) Amazon forests, possible methods of regeneration and improvement, Unasylva, 15, No. 2:63-69. (241: I 2; V B 1,3.)
- Pittier, H. (1939) Consideraciones acerca de la destruccion de los bosques e incendio de las sabanas, Boletin de la Sociedad Venezolana de Ciencias Naturales, 3, No. 26:291-302. (255: I 2; III G 0,1; IV D 3b; V B 2.)
- Rawitscher, F. (1952) Beiträge zum Frage natürlichen Verbreitung tropischer Savannen, Mitteilungen d. Geogr. Ges. Hamburg, 50:57-84. (241: I 3; II A 2; IV C 2,3; IV D 0,1,3.)
- Rawitscher, F., M. G. Ferri, M. Rachid (1948) The water economy of the vegetation of the "campos cerrados" in southern Brazil, Jour. of Ecol., 36, No. 2:236-268. (241: I 3; II A 2; II B 0; III B 0,1; III D 0; III G 0.)
- Rodriguez, A. (1952) Efectos de la quema sobre los suelos de la serie Chinchina, Bol. Informativo, 3, No. 30:34-46, Centro Nacional de Investigaciones de Cafe, Federacion Nal. de Cafeteros, Chinchina, Colombia. (250: I 4; III B 0.)
- Rondon, Candido Mariano da Silva, (n.d.) Lectures delivered by . . . on the Roosevelt-Rondon Scientific Expedition and the Telegraph Line Commission; translated by R. G. Reidy and Ed Murray. Comissao de Linhas Estrategicas de Matto Grosso ao Amazonas, Publicacao, No. 43, Rio de Janeiro. (241: I 1; IV D 0.)
- Roosevelt, Theodore (1914) Through the Brazilian Wilderness, New York. (241: I 2; IV D 0,1,3b.)

- Sampaio, Alberto Jose de (1945) Fitogeografia do Brasil, Bibliotheca Pedagogica Brasileira, Ser. 5a, Vol., 35, 372 pp. (241: I 1.2: IV D 1.)
- Schmidt, C. B. (1945) "O fogo e as seus perigos." Revista Rural Brasileira, 25(302):20-25. (241: I 2: II A 2; II B 0; III D 0.1,2,3; V B 2.)
- Schulz, J. P. (1960) Ecologic studies on rain forest in Northern Surinam, Van Eedenfonds, Amsterdam, 267 pp. (252: I 4: IV A 0,1: IV C 0,2,3; IV D 2.)
- Scutaru, D. M. (1956) Fogo no mato, Minas Gerais, Dept. de Prod. Veg., B. de Agr. 5, No. 11-12, 71-77. (241: I 1: II B 0,2.)
- Smith, A. C. (1945) The vegetation of the Guianas, in: Verdoorn, F. (ed.), Plants and plant science in Latin America. Chronica Botanica. Waltham, Mass., pp. 295-297 (251. 252, 253: I 2: IV D 1.)
- Smith, Lynn T. (ed.) (1963) Brazil. people and institutions, Louisiana State University Press. Baton Rouge, 667 pp. (241: I 4: II A 1: II B 2,3: IV A 0,1: IV B 0,1; IV C 0: V A 3: V B 0.1,2: V C 1.)
- Sociedad Antioquena de Agricultores (1950/1951) Tala de bosques - las quemas. Sociedad Antioquena de Agr., B. Agr., 376/381:3226-3228. (251: I 1: V A 3; V B 1.)
- Solorzano, M. C. F. (1960) El control de incendios en Venezuela, Agr. Venezol., 24, No. 220:40-43. (255: I 1: II B 3: V B 1: V C 1.)
- Solorzano, C. F. (1959) La quema racional. Agr. Venezol., 23, No. 213:2-3, 23-24. (255: I 1; III D 0,1,2; III E 0.)
- Solorzano, C. F. (1960) Campana intenseva contra incendios forestales, Agr. Venezol., 23, No. 216:43-44. (255: I 1: II B 0: V B 1: V C 1.)
- Solorzano, M. and F. Carlos (1963) Contrafuegos. Republica de Venezuela, Ministerio de Agricultura y Cria, Zona No. 1. Maracaibo, 53 pp. (255: I 3; II B 0.4: V A 0.)
- Stewart, Norman R. (1965) Migration and settlement in the Peruvian montaña: the Apurimac Valley. Geog. Rev., 55, No. 2:143-157 (261: I 2: IV A 4: IV B 4.)
- Suarez de Castro, Fernando (1953) Algunos efectos de las quemas sobre el suelo y las cosechas, Bol. Informative, 4 No. 41:9-32, Centro Nacional de Investigaciones de Cafe, Federacion Nal. de Cafeteros, Chinchina, Colombia. (250: I 4; III D 0,1,2,3: V B 1.)

- Suarez de Castro, F. (1953) Las quemas prescritas y su importancia en la conservacion de los suelos, Agr. Trop. (Colombia), 9:55-56. (250: I 0; II A 1; V B 0,2; V C 1.)
- Tamayo, Francisco (1962) Adaptaciones de la vegetacion pirofilica, Boletin de la Sociedad Venezolana de Ciencias Naturales, 23, No. 101:49-58. (255: I 3; II B 0,1,2; III E 0,1,2.)
- Tamayo, Francisco (1961) El medio llanero y la Estacion biologica de los llanos, Boletin de la Sociedad Venezolana de Ciencias, 22, No. 100:226-232. (255: I 3; II B 0; IV A 3; IV C 0,1; IV D 0,1.)
- Tamayo, Francisco (1962) Incendio de sabanas: Procedimiento irracional y ruinoso, Reprint from: 1º Forum de Conservación de Recursos Naturales, repaged pp. 3-8, Caracas. (255: I 3; III D 0; III E 1; III G 0.)
- Up de Graff, Fritz W. (1923) Head hunters of the Amazon: seven years of exploration and adventure, Duffield and Company, New York, 337 pp. (260: I 2; V A 3.)
- Vareschi, Volkmar (1962) La quema como factor ecologico en los llanos. Boletin de la Sociedad Venezolana de Ciencias Naturales, 23, No. 101:9-31. (255: I 4; II A 2; II B 4,5; III D 0; III E 1,2,3; IV C 0,1,2,3.)
- Venezuela, Ministerio de Obras Publicas (1964) Anuario climatologico 1963, Republica de Venezuela, Ministerio de Obras Publicas, Direccion de Obras Hidraulicas, Publicacion Tecnica 4, Caracas, Venezuela, 234 pp. (255: I 4; IV A 0,1,2.)
- Venezuela, Ministerio de Obras Publicas (1963) Atlas de profundidad - duracion - frecuencia de lluvias en Venezuela, Republica de Venezuela, Ministerio de Obras Publicas, Direccion de Obras Hidraulicas, Publicacion Tecnica 2, Caracas, Venezuela, 62 pp. (255: I 4; IV A 0.)
- Venezuela, Ministerio de Obras Publicas (1963) Lluvias extremas para 1,3,6,9,12, y 24 horas de 84 estaciones escojidas y lluvias extremas diarias de una seleccion de 51 estaciones, Republica de Venezuela, Ministerio de Obras Publicas, Direccion de Obras Hidraulicas, Publicacion Tecnica 3, Caracas, Venezuela, 184 pp. (255: I 4; IV A 0.)
- Venezuela, Ministerio de Obras Publicas (1962) Totales mensuales de lluvia de 233 estaciones escojidas, Republica de Venezuela, Ministerio de Obras Publicas, Direccion de Obras Hidraulicas, Publicacion Tecnica 1, Caracas, Venezuela, 168 pp. (255: I 4; IV A 0.)

- Vogt, William (1946) The population of Venezuela and its natural resources, Pan American Union, Washington, D.C., 52 pp. (255: I 4; III B 0.)
- Waddell, Eric W (1963) The anthropic factor in a savanna environment, M.A. thesis, McGill University, Department of Geography, Montreal, 203 pp. (251: I 4; II A 0,2; II B 0,2,3,4,5; III A 1,2; III B 0,2; III E 0,1,2,3; III F 0,1,2; III G 0,1; IV A 0,1,2; IV C 0,1,2,3; IV D 0,1; V A 0,3; V B 0,1,3; V C 1.)
- Wagley, Charles and Eduardo Galvao (1948) The Tapirape, Bur. of Am. Ethnology, Bull, 143, No. 3:167-178. (241: I 3; II A 1; V A 3; V B 2.)
- Waibel, Leo (1949) A vegetacao e o uso da terra no Planalto Central, Rev. Bras. Geog., Ano X, No. 3:335-380. (241: I 2; IV C 3; IV D 1,2,3b.)
- Waibel, Leo (1948) Vegetation and land use in the Planalto Central of Brazil, Geog. Rev., 38, No. 4:529-554. (241: I 2; IV C 3; IV D 1,2,3.)
- Watters, R. F. (1965) Shifting cultivation in Venezuela, F.A.O. Report (Forestry and Forest Division), 140 pp. (manuscript). (255: I 3; II A 2; II B 0; III C 1,2; III D 0,1,2; III E 0,1; III F 0; III G 0; IV A 0,1; IV C 0,3; V A 0,2,3; V B 0,1,2; V C 0,1.)
- Weck, J. (1964) Die Araukarien-Region von Südbrasilien und die Folgerungen aus der Waldbrandkatastrophe vom September 1963, Allg. Forstzeitg., 19, No. 3:38-42. (241: I 3; II A 1; II B 0,2,3,5; IV A 0.)
- West, Robert C. (1957) The Pacific Lowlands of Colombia, Studies, Social Science Series, Louisiana State University, No. 8, 278 pp. (250: I 4; II A 2; IV C 0,3; V A 3.)
- White, C. L. and J. Thompson (1955) Llanos - a neglected grazing resource, Jour. of Range Management, 8, No. 1: 11-17. (255: I 2; IV D 0.)
- Wijmstra, T. A. and T. van der Hammen (1965) Palynological data on the history of tropical savannas in northern South America, Unpublished manuscript, 30 pp. (240: I 4; III C 2; III E 1; III G 0; IV C 0,2; IV D 1,2,3a.)

Asia

- Abeywickrama, B. A. (1959) The vegetation of the lowlands of Ceylon in relation to soil, Tropical Soils and Vegetation, UNESCO, Abidjan Symposium, 1959, pp. 87-92. (336: I 2; IV D 3b; V A 3.)

- Agarwhal, S. C. (1959) Grasslands of Chakrata Forest Division, District Dehra Dun, Ind. For., 85, No. 11: 659-662. (340: I 2; IV D 3b.)
- Allen, B. C. (1908) Assam, in: The imperial gazeteer of India, Vol. 6, pp. 14-121. (340: I 3; II A 2; IV C 0,3; IV D 2,3; V B 0.)
- Anonymous (1961) 100 years of Indian forestry 1861-1961, Vol. II. Forest Research Institute, Dehra Dun, 381 pp. (340: I 2; II A 2; V B 2.)
- Asad Ali Anvery, Syed (1960) Progress in the integration of forestry and grazing with special reference to Pakistan, Fifth World Forestry Cong. 1960, Proc., 1:322-328. (166, 339, 340: I 3; IV D 1.)
- Baker, John R. (1937) The Sinharaja rain forest, Ceylon, Geog. Jour., 89, No. 6:539-551. (336: I 2; IV A 0,1,4; IV B 0,1,2; IV D 0,1,2; V A 0; V B 0.)
- Baker, Simon (1965) Land use along a tropical climatic boundary: the Walawe Ganga Basin of Ceylon, Ph.D. dissertation, Clark University, Worcester, Mass. (336: I 4; II A 1; II B 0; III B 0; IV C 2; IV D 1; V B 0,3; V B 3.)
- Banerjee, Rai Sahib A. L. (1942) A note on the Parklakimidi Forest Division, Ind. For., 68:66-74. (340: I 3; III B 0; IV A 0; IV D 3.)
- Biswas, P. C. (1956) Santals of the Santal Parganas, Bharatiya Adimjati Sevak Sangh, Delhi, 230 pp. (340: I 2; II A 2; V A 3.)
- Bor, N. L. (1938) A list of the grasses of Assam, Indian Forest Records (New Series), Botany, 1, No. 3:47-102, Government of India Press, Delhi. (340: I 2; IV D 0,1; V B 2.)
- Bor, N. L. (1942) The relict vegetation of the Shillong Plateau, Assam, Indian Forest Records (New Series), Government of India Press, 2, No. 6:152-195. (340: I 2; III G 0; V A 3; V B 0.)
- Burns, W., L. B. Kulkarni, and S. R. Godbole (1928) A Study of some Indian grasses and grasslands, Memoirs of the Dept. of Agriculture in India, Botanical Series, 14:1-57. (340: I 1; II A 1; II B 0; III B 0; IV D 0.)
- Burns, W., L. B. Kulkarni, and S. R. Godbole (1931) Succession in xerophytic Indian grasslands, J. of Ecol., 19, No. 2:389-391. (340: I 3; IV C 3.)

- Campbell, James M., ed. (1880) Gazeteer of the Bombay Presidency, Vol. 10, Ratnagiri and Savantavadi, Government Central Press, Bombay, 281 pp. (340: I 2; IV C 3.)
- Campbell, James M., ed. (1883) Gazeteer of the Bombay Presidency, Vol. 11, Kolaba and Janjira, Government Central Press, Bombay, 493 pp. (340: I 2; IV A 3; IV D 3; V B 2.)
- Campbell, James M., ed. (1884) Gazeteer of the Bombay Presidency, Vol. 21, Belgaum, Government Central Press, Bombay, 626 pp. (340: I 2; II A 2; IV C 0; IV D 0; V A 3.)
- Champion, H. G. (1923) The influence of the hand of man on the distribution of forest types in the Kumaon Himalaya, Ind. For., 49:116-136. (340: I 3; II A 2; IV D 0,1,3b.)
- Champion, H. G. (1929) The regeneration of tropical evergreen forests (rain forest), Ind. For., 55:429-446, 480-494. (339, 340, 351: I 3; II B 3; IV D 3b; V B 0.)
- Chapman, V. J. (1947) The application of aerial photography to ecology as exemplified by the natural vegetation of Ceylon, Ind. For., 73:287-314. (336: I 3; II A 2; III E 0; IV C 3; IV D 1,3b.)
- Chattertee, D. (1958) Tropical vegetation of Eastern India, Study of Tropical Vegetation, (Proceed. of Kandy Symposium), UNESCO, pp. 61-67. (340: I 2; IV D 3b.)
- Chaturvedi, M. D. and B. N. Uppal (1935) A study in shifting cultivation of Assam, Indian Council of Agricultural Research, Research Series No. 2, Indian Council of Agricultural Research, New Delhi, 20 pp. (340: I 2; IV C 3; IV D 3b; V B 2.)
- Chaudhuri, M. C. (1925) Bamboos in the Chittagong Hill tracts division, Bangal, Ind. For., 51:261-265. (339: I 2; III F 0,2; IV D 0; V A 3.)
- Chavan, V. M., N. Gopalkrishna, and R. A. Sangava (1960) Substitute for robbing in the western India, Ind. J. Agron., 5, No. 1:32-35. (340: I 3; III D 0,1,2; V B 1.)
- Cleghorne, Hugh Francis Clarke (1861) The forests and gardens of South India, W. H. Allen and Col., London, 412 pp. (340: I 2; II A 1; III F 0; V A 3.)
- Coombs, W. F. (1946) Certain aspects of chir (*Pinus longifolia*) regeneration, Ind. For., 73:39-42. (340: I 2; II B 3; III G 0,1; IV D 3,3b; V B 2.)

- C. W. Thornthwaite Associates (1963) Average climatic water balance data of the continents, Part II: Asia (excluding U.S.S.R.), Publications in Climatology, 16, No. 1:5-262, C.W. Thornthwaite Associates, Laboratory of Climatology, Centerton, New Jersey. (300: I 4; IV A 0,1.)
- Das, P. (1947) Panvin burning in some of the Upper Simla Hill states, Ind. For., 73:121-122. (340: I 2; II B 0; III G 0,1.)
- Davis, D. (1947) The influence of fire on chir (Pinus longifolia) regeneration, Ind. For., 73:336-337. (340: I 2; III B 0.)
- Dawkins, C. G. E. (1926) Fire protection in plantations, Ind. For., 52, No. 11:561-565. (340: I 1; II B 3; III B 0.)
- Dent, T. V. and S. N. Dabral (1947) Controlled burning in a Chir plantation, Ind. For. Bull., (G.C. Bulletin), No. 121, 35 pp. (340: I 4; II A 2; IV A 1; IV B 0,1; V B 0,1.)
- Edwards, M. V. (1930) Effect of burning of slash on soil and succeeding vegetation, Ind. For., 64:436-443. (340: I 2; III B 0.)
- Farmer, B. H. (1953) Tropical grasslands of Ceylon, Geog. Rev., 43, No. 1:115-117. (340: I 1; III B 0.)
- Furer-Heimendorf, Christoph von (1952) Ethnographic notes on some communities of the Wynad, East. Anthropol., 6:18-36. (340: I 1; V A 3; V C 1.)
- Furer-Heimendorf, Christoph von (1943) The aboriginal tribes of Hyderabad, Vol. I; The Chenchus, Macmillan & Co., London, 391 pp. (340: I 2; V A 1,3.)
- Furer-Heimendorf, Christoph von (1943) The aboriginal tribes of Hyderabad, Vol. II, The Reddis of the Bison Hills, Macmillan & Co., London, 364 pp. (340: I 3; V A 1,3; V B 0,2.)
- Furer-Heimendorf, Christoph von (1938) Through the unexplored mountains of the Assam-Burma border, Geog. Jour., 91:201-219. (340: I 1; V A 0,3.)
- Ghani, Q. (1965) Personal communication. (339: I 3; II B 2; III A 0,1; III B 0; IV A 0,1,2; IV D 2; V A 3; V B 1.)
- Gorrie, R. M. (1954) Forest fire control, Ind. For., 80:2-5. (340: I 1; II A 2; V B 1,2.)
- Gorrie, R. M. (1950) Patana fires in estates and water catchments, The Tropical Agriculturist, (Ceylon), 106, No. 3: 122-123. (336: I 2; IV D 3b; V B 1.)

- Griffith, A. L. (1946) The effects of burning on the soil as a preliminary to artificial regeneration, Ind. For. Bull., 130, 54 pp. (340: I 4; III D 0,1,2,3; II E 0,1; IV C 3.)
- Grigson, W. V. (1938) The Maria Gonds of Bastar, Oxford University Press, London, 350 pp. (340: I 3; II A 1; III F 2; V A 0; V B 2; V C 0,1.)
- Gurdon, P. R. T. (1914) The Khasis, Macmillan & Co. London, 232 pp. (340: I 3; III F 2; V A 3; V B 2.)
- Hakimuddin, M. (1953) Forest fires, Ind. For., 79:572-573. (340: I 2; III G 0,1; V B 2.)
- Henniker-Gotley, G. R. (1936) A forest fire caused by falling stones, Ind. For., 62:422-423. (340: I 0; II A 2; II B 0,1,2.)
- Hewetson, C. E. (1954) Fires and their ecological effects in Madhya Pradesh, Ind. For., 80:237-239. (340: I 1; II A 2; III B 0; V B 1.)
- Hewetson, C. E. (1950) Seventy-five year's fire protection in the tropics: Allapalli Forest Reserve, South Chanda, Madhya Pradesh (Central Provinces), India, (Bharat), Emp. For. Rev., 29, No. 4:339-350. (340: I 4; II B 2; III B 0; III E 0,1,2,3; IV A 0; IV D 0,2.)
- Holmes, C. H. (1958) The broad pattern of climate and vegetation distribution in Ceylon, Study of Tropical Vegetation (Proceed. of Kandy Symposium), UNESCO, pp. 94-114. (336: I 2; IV A 0,1; IV D 1.)
- Holmes, C. H. (1951) The grass, fern and savannah of Ceylon, their nature and ecological significance, Imp. For. Inst., Paper No. 28, 95 pp. (336: I 3; III G 0; IV D 1.)
- Jacob, M. C. (1939) A note on burning in sal forests, Assam Government Press, Shillong, 7 pp. (340: I 3; III D 0; III E 0,1; III G 0; IV D 1; V B 1.)
- Janaki, Ammal, E. K. (1958) Report on the humid regions of South Asia, Problems of Humid Trop. Regions, UNESCO, H. M. Stationery Office, London, pp. 43-53. (330: I 3; III G 0; IV A 0,1; IV D 1; V B 2.)
- Joachim, A. W. R. and S. Kandiah (1942) Studies on Ceylon soils, the chemical and physical characteristics of soils of adjacent contrasting vegetation formations, The Tropical Agriculturist, (Ceylon), 98, No. 2:15-30. (336: I 2; III G 0; IV C 3; IV D 2.)
- Joachim, A. W. R. and S. Kandiah (1948) The effects of shifting (chena) cultivation and subsequent regeneration of vegetation on soil composition and structure, The Tropical Agriculturist, (Ceylon), 104:3-11. (336: I 2; III B 0.)

- Kessell, S. L. (1938) Effect of burning of slash on soil and succeeding vegetation, Ind. For., 64:443-445. (340: I 1; III B 0; III G 0; V B 2.)
- Kessell, S. L. (1924) Review of damage caused by creeping fires, Ind. For., 50:541-547. (340: I 1; IV C 3.)
- Lord, L. (1936) The agricultural development of the Dry Zone of Ceylon. The Tropical Agriculturist, (Ceylon), 86:271-283. (336: I 0; V C 1.)
- Masani, N. J., K. Kedarnath and V. M. Mathur (1957) Notes on forest fire protection in India, Ind. For., 83, No. 5:339-346. (340: I 2; II A 2; II B 0; III E 3; IV D 0; V B 1.)
- Milroy, A. J. W. (1930) The relation between sal forests and fire, Ind. For., 56, No. 10:442-447. (340: I 2; III B 0; IV D 3b; V B 2.)
- Mitchell, B. A. (1963) Fires on idle land - the 1963 dry season, Malay. Forest., 26, No. 2:104-107. (348: I 1; II B 0,2; V C 1.)
- Mooney, H. F. (1942) A sketch of the flora of the Bailadila Range in Bastar State, Ind. For. Rec., 3, No. 7:197-253. (340: I 2; III G 0; IV D 0,3b.)
- Narayana-Murti, D. and R. Gopalachari (1943) Studies in fire resistance, Part I, The Forest Research Institute, 17 pp., Dehra Dun. (340: I 3; II B 4; III E 0.)
- Paul, W. R. C. (1936) Rotation cultivation in the "Wanni" of Ceylon, The Tropical Agriculturist, (Ceylon), 87: 362-370. (336: I 2; II A 1; V B 2.)
- Paul, W. R. C. (1949) Roving agriculture and the problems of dry farming, The Tropical Agriculturist, (Ceylon), 105:4-14. (336: I 1; II A 1; V B 2.)
- Prasad, J. (1950) Controlled burning in chir (Pinus longifolia), Ind. For., 72, No. 2:26-38. (340: I 3; III G 0; V E 1.)
- Prasad, V. N. (1957) Forest fire in Palamar district, Ind. For., 83, No. 1:54-55. (340: I 1; II B 0; V B 1.)
- Pring, N. G. and A. Bakhsh (1940) Fire protection in High Hill forests, Ind. For., 66:70-79, 135-146. (340: I 2; IV C 3; IV D 3b.)
- Puri, G. S. (1960) Indian forest ecology: a comprehensive survey of vegetation and its environment on the Indian Subcontinent, Oxford Book and Stationery Co., New Delhi and Calcutta, Vol. I., pp. 1-318, Vol. II, pp. 319-710. (340: I 4; II C 3; III D 0.)

- Puri, G. S. (1959) Vegetation and soil in tropical and sub-tropical India. Tropical Soils and Vegetation: UNESCO, Abidjan Symposium 1959, pp. 93-102. (340: I 3; IV A 0,1; IV C 3; IV D 2.)
- Rawat, A. S. (1949) Results of controlled burning in the sal plantations of Bengal, Ind. For., 75, No. 3:69-86. (340: I 2; II A 2; III G 0,1; V B 1.)
- Rosayro, R. A. de (1949) Some aspects of shifting cultivation in Ceylon, The Trop. Agriculturist, (Ceylon), 105: 51-58. (336: I 2; II A 2; III D 0,1; III E 1; V B 2; V C 1.)
- Rosayro, R. A. de (1945-1946) The montane grasslands (patanas) of Ceylon: an ecological study with reference to afforestation, The Tropical Agriculturist, (Ceylon), 101, No. 4:206-213; 102, No. 1:4-17; 102, No. 2:81-94; 103, No. 3:139-147. (336: I 1; V C 1.)
- Rosayro, R. A. de (1943) The soils and ecology of the wet evergreen forests of Ceylon, The Tropical Agriculturist, (Ceylon), 98, No. 2:4-14; 98, No. 3:13-36. (336: I 3; IV C 3; IV D 2.)
- Rosayro, R. A. de (1958) Tropical ecological studies in Ceylon, Study of Tropical Vegetation (Proceed. of Kandy Symposium), UNESCO, pp. 33-39. (336: I 3; IV D 1.)
- Senaratna, J. E. (1942) Patana burning with particular reference to pasturage and wet patanas, The Trop. Agriculturist, (Ceylon), 98, No. 4:3-16. (336: I 3; II A 2; II B 4; III D 2; III E 0,1,2,3; III G 0; IV A 0,2; IV C 3; IV D 0,2,3b; V B 2; V C 0,1.)
- Senaratna, S. D. J. E. (1958) Regional survey of the grassland of Ceylon, Study of Tropical Vegetation (Proceed. of Kandy Symposium), UNESCO, pp. 175-182. (336: I 4; IV D 2.)
- Serevo, Tiburcio S. (1953) Forest fire protection in the Philippines, Eighth Pacific Science Congress, Abstract of Papers, National Research Council of the Philippines 1953, p. 350-351. (366: I 1; II B 0,1; V B 1.)
- Seth, S. K. and M. S. Waheed Khan (1960) An analysis of soil moisture regime in sal (Shorea robusta) forests of Dehra Dun, with references to natural regeneration, Ind. For., 86, No. 6:323-335. (340: I 2; III B 0; V B 2.)
- Shankarnaryan, K. A. and M. V. Dabholkar (1959) Studies on the vegetation of Salem District (S. India), Ind. For., 85, No. 10:577-580. (340: I 3; IV D 2.)
- Shebbeare, E. O. (1932) Sal taungyas in Bengal, Empire Forestry Jour., 11, No. 1:18-33. (340: I 2; II A 1; III G 0; V B 2,3.)

- Soyza, Duncan J. de (1944) Hill paddy cultivation in Ceylon, The Tropical Agriculturist, (Ceylon), 100. No. 4:211-218. (336: I 2; V A 3; V B 2)
- Stockdale, F. A. (1926) Chena problem and some suggestions for its solution, The Tropical Agriculturist, (Ceylon), 66:199-206. (336: I 2; III D 0,2; V B 1)
- Stracey, P. D. (1954) Forestry in Assam, Ind. For., 30:759-769. (340: I 2; IV D 0.)
- United States Air Force (1965) Far East climatic atlas, 20th Weather Squadron, 1st Weather Wing. Special study 105-7, San Francisco, 243 pp. (300, 330: I 4; IV A 0,1,2,3.)
- White, J. S. L. (1945) Notes on the opening by manual labour of land in the dry zone of Ceylon, The Trop. Agriculturist, (Ceylon), 101:148-152. (336: I 2; II A 2; V B 0,1,3.)
- Wikramatileke, Rudolph (1963) Southeast Ceylon: trends and problems in agricultural settlement, U. of Chicago, Chicago, 163 pp. (336: I 4; IV A 3; IV D 0,1.)
- Willis, J. C. (1922) Agriculture in the tropics, University Press, Cambridge, 224 pp. (336: I 1: V B 2.)
- Wroughton, F. H. (1948) To burn or not to burn, So. African Forestry Assoc. J., 16:76-78. (340: I 1; III E 0,1.)

Southeast Asia

- Allen, C. W. (1916) Teak taungya plantations in the Henzade-Maubin division, Ind. For., 42:533-537. (351: I 3; III B 0; IV D 3b.)
- Allouard, P. (1951) Better conditions for rural populations in tropical forest areas, Unasylva, 5:99-162. (357: I 3; III A 0; III B 0; III G 1,2; V A 0; V A 3.)
- Allouard, P. (1951) Forest fire control in tropical countries- Experience in Cambodia, United Nations Sci. Conf. Conserv. and Util. Resources, Proc., 5:43-49. (357: I 2; II B 0,4; III E 0; V A 3; V B 1; V C 1.)
- Allouard, P. (1950) La lutte contre les incendies de forêts dans les pays tropicaux: examen de l'expérience acquise au Cambodge, Rev. Int. Prod. Colon., No. 251/252:151-156, 253:177-180. (357: I 2; II B 0,4; III E 0; V A 3; V C 1.)
- Allouard, P. M. (1937) Pratique de la lutte contre les feux de brousse, Inst. des Recherches Agron. et Forestières, Hanoi, 21 pp. (353: I 2; II B 0; V B 1.)
- Allsop, F. (1953) Shifting cultivation in Burma: its practice, effects and control, and its use to make forest plantations, Seventh Pacific Science Cong., Proc., 1949, 6:277-285. (351: I 3; IV D 1,3b; V B 0,1,2.)

- Annandale, Nelson and Herbert C. Robertson (1903) Contributions to the ethnography of the Malay Peninsula, Anthropology, 1:1-72. Longmans, Green and Co., London. (358: I 1; III B 0; V A 3; V B 0,2.)
- Anonymous (1952) Colony of North Borneo, Annual report 1951, Government Printing Department, Jesselton, North Borneo, 131 pp. (364: I 2; II A 1; V A 1,3.)
- Anonymous (1959) Fire damage and borers, Planters' Bulletin of the Rubber Research Institute of Malaya, 40: 36-37. (358: I 2; III G 0,1.)
- Anonymous (1957) Jungle clearing, Planters' Bulletin of the Rubber Research Institute of Malaya, 33:105-107. (358: I 2; V B 2.)
- Anonymous (1956) Sodium chlorate weedkiller, Planters' Bulletin of the Rubber Research Institute of Malaya, 27:111. (358: I 4; II B 0.)
- Anonymous (1955) Wounds and their treatment, Planters' Bulletin of the Rubber Research Institute of Malaya, 17:28. (358: I 2; II B 2; III G 0,1.)
- Arnot, D. B. and J. S. Smith (1937) Shifting cultivation in Brunei and Trengganu, Malay. For., 6:13-17. (375: I 2; V C 1.)
- Atkinson, D. J. (1948) Forests and forestry in Burma, Jour. Roy. Soc. Arts, 96:478-491. (351: I 2; III B 0; V A 3.)
- Baja, H. A. (1959) Forest fires, Forestry Leaves, 11, No. 3:23-24. (366: I 3; II A 2; II B 0; III D 0; III E 0,3.)
- Barrera, Alfredo (1964) Classification and utilization of some Philippine soils, Jour. of Trop. Geog., 18: 17-29 (366: I 4; II A 1; IV A 2,3.)
- Barthelemy, (Pierre F. S.) Marquis de (1904) Au pays moi, Plon-Nourit & Cie, Paris. (353: I 2; III B 0.)
- Barton, Roy Franklin (1922) Ifugao economics, U. of California Publications in American Archeology and Ethnology, 15, No. 5:385-446. (366: I 3; IV D 1,2; V B 0.)
- Barton, Roy Franklin (1938) Philippine pagans: the autobiographies of three Ifugaos, George Routledge and Sons, London, 271 pp. (366: I 1; III B 0; V A 0,3.)
- Barton, Roy Franklin (1949) The Kalingas: their institutions and custom law, University of Chicago Press, Chicago, n.p. (366: I 1; III B 0; V A 3; V B 2.)

- Benedict, Laura Watson (1916) A study of Bagobo ceremonial, magic and myth, Annals N.Y. Acad. Sci., Vol. 25, 308 pp. (366: I 2; II A 1; V A 3.)
- Bernatzik, Hugo Adolf und Emmy (1941) Die Geister der gelben Blaetter: Forschungsreisen in Hinterindien, Koehler & Voigtlander, Leipzig, 240 pp. (357: I 0; V A 3.)
- Blanford, H. R. (1918) Note on operations in bamboo flowered areas in Yatha division, Ind. For., 44:550-560. (351: I 3; II A 0; IV D 3b.)
- Blanford, H. R. (1925) Regeneration with the assistance of taungya in Burma, Ind. For. Rec., 2, No. 3:81-121. (351: I 2; V B 2.)
- Bonifacy, _____, (Commandant) (1905) Monographie des mans Quan-Trang, Revue Indo-Chinoise, Vol. 8, n.s., 3:1597-1613. (355: I 2; II A 2; V B 2.)
- Brien, M. (1885) Aperçu sur la province de Battambang, Cochinchine française, Excursions et Reconnaissances, 10: 341-356. (357: I 2; IV C 2.)
- Brown, William H., and Donald M. Mathews, (1914) Philippine dipterocarp forests, Philippine Journ. Sci., Sect. A, 9, No. 5 and 6:413-568. (366: I 2; IV A 3; IV D 3b; V A 3.)
- Brown, William H. (1919) Vegetation of Philippine mountains, Bureau of Printing, Manila. 434 pp. (366: I 3; IV D 3b.)
- Charlton, J. (1936) A note on the effects of taungya on Burma forest soils, Agr. and Livestock, India, 6, No. 1: 54-59. (351: I 3; III C 0,1,2; III E 0,1.)
- Chemin-Dupontès, Paul (1909) La question forestière en Indo-Chine, Bul. Comité de l'Asie Française, 9, No. 101: 340-348. (353: I 2; III E 3; V A 3.)
- Clarkson, James (1965) Personal communication. (358: I 2; II A 1; II B 0; III F 2; V A 3.)
- Cole, Fay-Cooper (1913) The wild tribes of the Davao District, Mindanao, Field Museum of Natural History, Anthropological Series, 12:48-203. Field Museum of Natural History, Chicago. (366: I 1; II A 1; V A 3.)
- Cole, R. (1959) Temiar Senoi agriculture: a note on aboriginal shifting cultivation in Ulu Kelantan, Malaya, Part II, Malay. For., 22, No. 3:191-207. (358: I 1; II A 2; V C 0.)
- Collenette, P. (1963) A physiographic classification of North Borneo, Jour. of Trop. Geog., 17:28-33. (361: I 2; IV C 0,3.)

- Conklin, Harold C. (1957) Hanunoo agriculture: a report on an integral system of shifting cultivation in the Philippines, FAO Forestry Development Paper, No. 12, 209 pp. (366: I 2; III B 0; III F 0,2; V A 3; V B 2.)
- Conklin, Harold C. (1957) Hanunoo agriculture in the Philippines, Unasylva, 11, No. 4:172-173. (366: I 3; II A 2; V B 0,1.)
- Conklin, Harold C. (1959) Shifting cultivation and succession to grassland climax, Proceedings of the Ninth Pacific Sci. Congress, of the Pacific Science Association, 1957, 7:60-62. (366: I 3; III A 0; III B 0; IV D 0; V B 0,2.)
- Consigny, A. (1936) Considérations sur les feux de brousse, leurs méfaits et la possibilité de les enrayer, Bull. Econ. de l'Indochine, 39:183-195. (353: I 3; II A 2; V B 2.)
- Coulter, J. K. (1950) Organic matter in Malayan soils: a preliminary study of the organic matter content in soils under virgin jungle, forest plantations and abandoned cultivated land, Malay. For., 13:189-202. (358: I 3; III D 0; IV C 3.)
- Credner, Wilhelm (1935) Siam: das Land der Tail: eine Landeskunde auf Grund eigener Reisen und Forschungen, J. Engelhorn's Nachf., Stuttgart, 422 pp. (352: I 3; II A 2; III B 0; III G 0,1; IV D 0.)
- Cuisinier, Jeanne (1946) Les Mu' o' ng, géographie humaine et sociologie, Institut d'Ethnologie, 618 pp. (353: I 1; V B 1.)
- Dacanay, Placido (1932) Reafforestation of grasslands in the Philippines, Empire Forestry Jour., 11, No. 1:13. (366: I 2; II B 3; IV D 3b.)
- Dale, W. L. (1963) Surface temperatures in Malaya, Jour. of Trop. Geog., 17:57-71. (353: I 4; IV A 1.)
- Dale, W. L. (1964) Sunshine in Malaya, Jour. of Trop. Geog., 19:20-26. (358: I 4; II A 1; IV A 1.)
- Dale, W. L. (1959) The rainfall of Malaya, Part I and II, Jour. of Trop. Geog., 13:23-37; 14:11-28. (358: I 4; II A 2; IV A 0,1,2,3,4; IV B 0,2.)
- Davis, A. P. (1923) Forest village in Burma, Ind. For., 49, No. 12:641-645. (351: I 0; II A 1; II B 0; V A 3; V B 2.)
- Dickerson, Roy E. et al., (1928) Distribution of life in the Philippines, Monographs of the Bureau of Science, Philippine Islands, No. 21, Bureau of Printing, Manila, 322 pp. (366: I 2; II A 2; IV D 3b; V A 3.)

- Dobby, Ernest Henry George (1954) Southeast Asia, University of London Press. London, 415 pp. (350: I 1; V A 0.)
- Dudal, R. and F. R. Moormann (1964) Major soils of Southeast Asia: their characteristics, distribution, use and agricultural potential, Jour. of Trop. Geog., 18:54-80. (350: I 4; IV C 3; IV D 1.2.)
- Ealdama, Eugenio (1938) The Montes of Panay, Philippine Magazine, 35, No. 1:24,25,50-51; No. 2:95-97, 197; No. 3:138,149,150; No. 4:236,242-245; No. 5:286,287; No. 6:468,469,487-490. (336: I 1; II A 2; V A 3.)
- Fernandez, S. P. and J. A. Evangelista, (1952) Illegal kaingin: a national arson, Forestry Leaves, 5, No. 4: 23-24,30. (366: I 1; V B 1.)
- Ferrars, Max and Bertha (1900) Burma. Samson Low, Marston & Company, London, 278 pp. (351: I 3; III F 0,2; V B 2.)
- Fox, Robert B. (1952) The Pinatubo region: their useful plants and material culture, Philippine Jour. Sci., 81: 174-414. (366: I 1; III B 0; IV D 0, V A 3; V C 1.)
- Frake, Charles O. (1955) Social organization and shifting cultivation among the Shindangan, Ph.D. dissertation, Yale University, New Haven. 311 pp. (366: I 2; V A 0,3.)
- Francis, E. C. and G. H. S. Wood (1954) The classification of vegetation of North Borneo from aerial photographs, Malay. For., 18:38-44. (364: I 3; IV D 0,1.)
- Garfitt, J. E. (1941) Malayan forest types, Malay For., 10:136-140. (358: I 3; IV D 0.)
- Garvan, John M. (1931) The Manobos of Mindanao, Mem. Nat. Acad. Sci., 23, 265 pp., Government Printing Office, Washington, D.C. (366: I 2; II A 2; V A 3; V B 0.)
- Gawthorn, D. J. (1962) Jungle clearing, Planters' Bulletin of the Rubber Research Institute of Malaya, 62: 103-108. (358: I 2; V B 1)
- Gilliland, H. B. (1963) Geographical distribution of Malayan grasses, Jour. of Trop. Geog., 17:20-23. (358: I 4; IV D 1,3b.)
- Gourou, Pierre (1936) Les paysans du delta tonkinois: étude de géographie humaine, Editions d'Art et d'Histoire, Paris, 666 pp. (357: I 2; III B 0; V B 0.)
- Gourou, Pierre (1940) L'utilisation du sol en Indochine française, Centre d'Etudes de Politique Etrangère, Travaux des Groupes d'Etudes, Publ. No. 14, 446 pp. (353: I 1; II B 2,3; III B 0; V B 2.)

- Grant, J. (1949) Brunei: Annual report for the year 1949, Reviewed by T. A. Strong in Empire Forest Review, 29: 384-385. (1950) (361: I 1; V B 1.)
- Grist, Donald (1936) Malaya: agriculture, Malayan Information Agency, London, 101 pp. (358: I 1; V C 1.)
- Grist, Donald (1955) Rice, Longmans, Green & Company, London, 333 pp. (358,351: I 1; III B 0; V C 1.)
- Hoffet, J. H. (1933) Les mois de la chaîne annamitique entre Tourane et les Boloven, Terre, Air, Mer: La Géographie, 59:1-43. (354,355: I 3; V A 1,3.)
- Holttum, R. E. (1954) Adinandra belukar: a succession of vegetation from bare ground on Singapore Island, Malayan Jour. of Trop. Geog., 3:27-32. (358: I 3; IV D 1,2,3b.)
- Huke, R. E. (1954) Economic geography of a North Burma Kachin village, Unpublished: presented at the meetings of the Far Eastern Association, New York, April 13-14, 1954, 24 pp. (351: I 4; II A 1; III B 0; IV C 2; V A 3; V B 2,3.)
- Huard, P., et A. Maurice (1939) Les mnong du plateau central indochinois, Institut Indochinois pour l'Etude de l'Homme. Bulletins et Travaux, 2, Fasc. 1:27-148. (353: I 3; II A 2; III F 0; IV D 0,3b; V A 0.)
- Izikovitch, G. K. (1951) Lamet, jungle peasants of Indochina, East. Anthropol., 4:124-132. (354: I 2; II A 1; V A 0,1,3; V B 2.)
- Izikowitz, K. G. (1951) Lamet Hill peasants in French Indochina, Etnologiska Studier, 17:1-37b. (354: I 3; V A 3.)
- Kittinanda, S. P. (1963) Natural regeneration of teak at Lampang, Vanasarn, 21, No. 4:261-268. (352: I 4; III E 0,1,2; IV D 0,1,2.)
- Kostermans, A.J.G.H. (1958) Note on lowland vegetation in equatorial Borneo, Study of Tropical Vegetation (Proceed. of Kandy Symposium), 1958, UNESCO, pp. 154-158. (361: I 2; IV D 3b.)
- Kurz, Sulpice (1875) Preliminary report on the forest and other vegetation of Pegu, C.B. Lewis, Baptist Mission Press, 34 pp. (351: I 1; II B 0,2; IV D 3b; V B 0.)
- Letourneaux, Charles (1957) Tree planting practices in tropical Asia, FAO Forestry Development Paper, No. 11, 172 pp. (350: I 3; III E 1; V A 3; V B 0; V C 0.)

- Milne, Mrs. Leslie (1924) The home of an eastern clan: a study of the Palaungs of the Shan States, Clarendon Press, Oxford, 428 pp. (351: I 2; III E 3; V A 3; V B 2.)
- Myint, A. U. (1956) The use of aerial survey in managing Burma forests, Burmese For., 6, No. 2:181-187. (351: I 2; III G 0,1.)
- Nano, Jose F. (1939) Kaingin laws and penalties in the Philippines, Philippine Jour. For., 2, No. 2:87-92. (366: I 2; II B 3,5; III G 0,1; V B 1.)
- Nuttonson, M. Y. (1963) Physical environment and agriculture of Burma, Amer. Inst. of Crop Ecology, Washington, D.C., 142 pp. (351: I 4; IV A 0,1; IV B 0,2; IV D 0,1; V A 3; V B 3.)
- Oracion, Timoteo S. (1963) Kaingin agriculture among the Bukidnons of South-Eastern Negroes, Philippines, Jour. of Trop. Geog., 17:202-212. (366: I 3; II A 1; IV A 0,3; IV C 0,3; V A 2; V B 0,2,3.)
- Overholt, Dr. William (1963-64) Personal communication. (366: I 1; II A 2; II B 1,3; III B 0; III F 0,2.)
- Panton, W. P. (1962) The 1962 soil map of Malaya, Jour. of Trop. Geog., 18:118-124. (358: I 3; III F 0; IV C 3.)
- Paton, J. R. (1964) The origin of the limestone hills of Malaya, Jour. of Trop. Geog., 18:134-147. (358: I 2; IV C 3.)
- Pendleton, Robert L. (1942) Land utilization and agriculture of Mindanao, Philippine Islands, Geog. Rev., 32:180-210. (366: I 1; III B 0; IV D 3b; V A 3.)
- Pflueger, O. W. (1930) The "kaingin" problem in the Philippines and a possible method of control, Jour. For., 28, No. 1:66-71. (366: I 2; II B 0; III E 0.)
- Prakong, Intraghand (1965) The growth study of dry dipterocarp tree species with and without fire protection, Faculty of Forestry, Kasetsart University, Thailand, unpubl. progress report, 1 p. (352: I 4; III E 0.)
- Ramage, C. S. (1964) Diurnal variation of summer rainfall of Malaya, Jour. of Trop. Geog., 19:62-68. (358: I 4; II A 1; IV A 3; IV B 0.)
- Robbins, R. G. and J. Wyatt-Smith (1964) Dry land forest formations and forest types in the Malayan peninsula, Malay. For., 27, No. 3:188-216. (358: I 3; IV D 2.)

- Rodriguez, F. G. (1958) Problems of the humid tropical Philippines with special reference to water resources development, Problems of Humid Tropical Regions. Humid Tropics Research, UNESCO, pp. 86-99. (366: I 2; V B 2.)
- Sandeson, S., C. P. Menon, and S. Ganapathy (1962) Notes on the burning of jungle, Planters' Bulletin of the Rubber Research Institute of Malaya. 62:109-112. (358: I 2; II B 0; V B 1.)
- Spate, O. H. K. (1945) The Burmese village, Geog. Rev., 35: 523-543. (351: I 1; IV A 1.)
- Spurway, B. J. C. (1937) Shifting cultivation in Sarawak, Malay. For., 6:124-128. (375: I 1; II A 1; V B 2.)
- Stamp, L. Dudley (1925) The vegetation of Burma from an ecological standpoint. Thacker, Spink and Co., Calcutta, 65 pp. (351: I 2; IV C 2; IV D 1,3b; V A 3.)
- Sulit, Carlos (1947) Forestry in the Philippines during the Japanese occupation, Philippine Jour. For., 5, No. 1: 22-49. (366: I 1; II B 3; III G 0,1.)
- Symington, C. F. (1933) The study of secondary growth on the rain forest sites, Malay. For., 2:107-117. (358: I 2; III E 0,1.)
- Thailand (1964) National progress report on forestry, Thailand, period 1962/1964, Royal Forest Dept. Bangkok, Thailand, Asia Pacific Forestry Commission, Seventh session, Rotorua, New Zealand, Sept.- Oct. 1964, 11 pp. (352: I 4; IV D 3; III E 0; V A 3; V B 1.)
- Tin Htut, U. (1955) A note on shifting cultivation, Burmese For., 5, No. 2:108-109. (351: I 1; II A 1; II B 0,3; V B 2.)
- Tubb, J. A. (1959) Shifting cultivation and inland fisheries, Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association, 1957, 7:68-70. (352: I 2; III B 0; III C 2; III D 2.)
- Turbang, J. (1961) Forest and grassland fires in the Lower Mekong Basin. Report of FAO to ECAFE, Committee for Co-ordination of Investigations of the Lower Mekong Basin, Twelfth session, Saigon, Vietnam, Feb. 1961, 44 pp. (350: I 4; II B 0,2,4; III A 3; III B 0,2,4; III C 0,1,2,3; III D 0,1,2; III E 1,3; III G 0,1; V A 0,3; V B 2,3,4; V C 0.)
- United States Air Force (1964) Technical Services, Climatic atlas of Indochina (excluding Malaya and Burma), 20th Weather Squadron, 1st Weather Wing, Special Study 105-6, San Francisco, 265 pp. (353: I 4; IV A 0,1,2,3.)

- United States Department of Agriculture (1965) Agricultural economy of North Vietnam, ERS Foreign 123, Dept. of Agriculture, ERS Service, Washington, D.C., 37 pp. (355: I 3; IV D 0; V B 1.)
- Vandermeer, Canute (1963) Corn cultivation on Cebu: an example of an advanced stage of migratory farming, Jour. of Trop. Geog., 17:174-177. (366: I 3; II B 3; III B 0; V A 3.)
- Vandermeer, Canute (1965) Personal communication. (366: I 2; V A 0; V C 1.)
- Vidal, J. (1956) La végétation du Laos, Part I: Le milieu, Trav. Lab. Forestier Toulouse, Vol. 1, 120 pp. (354: I 2; IV A 0,1; IV C 3.)
- Vidal, J. (1958) La végétation du Laos, Part II: Groupements végétaux et flore, These Doct. es sciences naturelles, Toulouse. (354: I 2; IV A 0,1; IV C 3; IV D 2; V A 3.)
- Wyatt-Smith, J. (1964) A preliminary vegetation map of Malaya with descriptions of the vegetation types, Jour. of Trop. Geog., 18:200-213. (358: I 4; III B 0; IV D 0,2,3b.)
- Wycherley, P. R. (1963) Variation in the performance of Hevea in Malaya, Jour. of Trop. Geog., 17:143-171. (358: I 4; IV A 3; IV B 0.)

Indonesia

- Adriani, N. and Alb. C. en Kruijt (1912) De Bare's-sprekende Toradjas van Midden-Celebes, Landsdrukkerij, Batavia, Vol. 1, 426 pp., Vol. 2, 468 pp., Vol. 3, 717 pp. (376: I 2; V A 3; V B 2.)
- Anas, M. (1960) The Highlands of Australian New Guinea, Geog. Rev., 50, No. 4:467-490. (378: I 1; IV D 0,3b.)
- Anonymous (1914) De eilanden Alor en Pavitar, Tijdschrift van het Koninklijk Nederlandsch aardrijkskundig Genootschap, ser. 2, 31:70-102. (371: I 3; V A 3; V B 2; V C 0,1.)
- Ardenne, Th. van (1912) Bijdrage tot de Kennis der To Lampoe, (Bijlage van Hoofdstuk IV, Het Stromgebied van de Kalaena Pt. I, pp. 64-68), in: Adriani, N., and A. C. Kruijt, De Bare's-sprekende Toradjas van Midden-Celebes, Landsdrukkerij, Batavia, Vol. 2. (371: I 3; III B 0; IV D 2,3b; V A 3; V B 2.)
- Ballot, A. (1904) Verslag betreffende een diehstreis van den Assistant-Resident van Loebog Sikaping A. Ballot...naar de landschappen Moeara Soengei Lolo Vi Kota Kampar en Mapat Toenggal (Sila-jang, Loebog Gedang en Moeara). Tijdschrift voor Indische Taal-, Land- en Volkenkunde 47: 471-551. (372: I 2; II A 2; III B 0; V A 3.)

- Bangert, C. (1860) Verslag der reis in de binnenwerts gelegene streken van Boesoen Ilir, Tijdschrift voor Indische Taal-, Land- en Volkenkunde, 9:134-218 (375: I 2; III B 0.)
- Bartlett, H. H. (1919) The manufacture of sugar from Arenca saccharifera in Asahan, on the east coast of Sumatra, Michigan Academy of Science, 21st report, pp. 157-158. (372: I 2; III G 0,1; V A 3.)
- Bartlett, H. H. (1935) The Batak lands of North Sumatra, from the standpoint of recent American botanical collections, Nat. and Appl. Sci. Bull., 4, No. 3:211-323, Univ. of the Philippines, Manila, Philippines. (372: I 3; IV D 2, 3b.)
- Blackwood, Beatrice (1950) The technology of a modern Stone Age people in New Guinea, Pitt Rivers Museum, Occasional Papers in Technology, 3 University Press, Oxford, 60 pp. (378: I 0; V A 3.)
- Blackwood, Beatrice (1939) Life on the upper Watut, New Guinea, Geog. Jour. 94:11-28. (378: I 0; IV D 3b; V A 3.)
- Bor, R. C. van den (1932) Adatrechtgegevens uit Sarolangoen (1905. Zuid-Sumatra, 140), in: Adatrechtbundels, 33, Sumatra, Martinus Nijhoff, 's-Gravenhage, 570 pp. (372: I 3; II A 2; V A 2,3; V B 2.)
- Bouman, M. A. (1922/1952) Gegevens uit Smitau en Boven-Kapuas. in: Adatrechtbundels, 44, Borneo, Martinus Nijhoff, 's-Gravenhage, 433 pp. (375: I 2; II A 2; V A 2,3.)
- Bowman, Robert G. (1948) Land settlement in New Guinea, New Zealand Geog., 4:29-54. (378: I 1; III B 0; IV D 0.)
- Brass, L. J. (1941) Stone Age agriculture in New Guinea, Geog. Review, 31:555-569. (378: I 1; IV D 0; V C 1.)
- Breda de Haan, J. van (1898) Regenval en reboisatie in Deli, Mededeelingen uit s Lands Plantentuin, 33, G. Kolff and Co., Batavia. (372: I 1; V B 1,2.)
- Brookfield, H. C. (1962) Local study and comparative method: an example from Central New Guinea, Annals, A.A.G., 52, No. 3:242-254. (378: I 2; II B 2; III B 0; V A 3.)
- Brookfield, H. C. and Paula Brown (1963) Struggle for land: agriculture and group territories among the Chimbu of the New Guinea Highlands, Oxford University Press, Melbourne, London, 193 pp. (378: I 3; II A 2; V A 0,1,8; V B 0,1,2; V C 0.)

- Conroy, W. I. (1953) Notes on some land-use problems in Papua and New Guinea, Austral. Geog., 6, No. 2:25-30. (370: I 1; III B 0; V A 3; V B 2; V C 1.)
- Drees, Meijer E. (1952) Silvicultural problems in dry monsoon areas in Indonesia, United Nations, FAO, Asian Pacific Forestry Commission, Second session, Singapore, December 1952. 8 pp., (mimeo.) (371: I 3; II A 2; III B 0; IV D 3b.)
- Elmberg, John-Eric (1955) Field notes on the Mejbrat people in the Ajamaru District of the Birds' Head (Vogelkop), Western New Guinea, Ethnos 20:2-102. (376: I 1; V A 3.)
- Evans, Ivor H. N. (1922) Among primitive peoples in Borneo: a description of the lives, habits and customs of the piratical headhunters of North Borneo, with an account of interesting objects of prehistoric antiquity discovered in the island, Seeley, Service and Company, London, 318 pp. (375: I 2; II B 2; III B 0; IV A 0; IV D 3b; V A 3.)
- Flemmich, Charles Onen (1940) History of shifting cultivation in Brunei 1906-1939, Malay. Agric. Jour., 28:234-239. (375: I 1; V A 3.)
- Fokkinga, J. (1948) Verslag van de Dienst van het Boswezen in Indonesia over de Periode 1940 t/m 1946, Archipel Drukkerij, Buitenzorg, 159 pp. (371: I 2; II B 3.)
- Gonggripp, J. W. (1938) Soil management and density of population, XV Congrès Intern. de Géographie, Amsterdam: Géographie Coloniale, p. 400 (372: I 2; IV D 3b.)
- Grabowsky, Fr. (1908) Der Reilsbau bei den Dajaken Südost Borneos, Globus, 93:101-105. (375: I 1; V A 3.)
- Hagreis, B. J. (1930/1931) Ladangbouw, Landbouw: Tijdschrift der Vereeniging van Landbouwconsulenten in Nederlandsch-Indië, 6:43-78, English summary: Ladang cultivation, pp. 76-78. (370: I 1; II B 3; V B 0.)
- Hannibal, L. W. (1952) Aerial forest photo interpretation in Indonesia, United Nations, FAO, Asian Pacific Forestry Commission, Second session, Report No. 75, 24 pp. (376: I 3; IV D 0.)
- Hannibal, L. W. (1956) Suggestions for the forest policy in Indonesia, Rimba Indonesia, 3:227. (371: I 1; III G 0; V B 1.)
- Herwerden, G. A. M. Hondius van (1916) Eenige beschouwingen over de bestrijding van den roofbouw der Inlandsche bevolking in Nederlandsch-Indië, Koloniaal Tijdschrift, 51:9-16, 145-164. (371: I 0; II A 2; III B 0; III F 0; V B 1.)

- Holmes, John Henry (1924) In primitive New Guinea: an account of a quarter of a century among the primitive Ipi and Namau groups of tribes in the Gulf of Papua.... with an introduction by Dr. A. C. Haddon, Seeley, Service and Co. London, 307 pp. (379: I 3; V A 2,3; V B 2.)
- Hose, Charles and William McDougal (1912) The pagan tribes of Borneo: a description of their physical, moral and intellectual condition. 2 vols., Macmillan and Co., London, n.p. (375: I 3; II A 2; V A 3; V B 2.)
- Hueting, A. (1906) De Zending en de Landbouw, Mededeelingen van Wege het Nederlandsche Zendinggenootschap, 50:387-412. (371: I 3; II A 2; V B 0,2.)
- Lane-Poole, C. E. (1925) The forests of Papua and New Guinea, Empire Forestry Jour., 4:206-226. (378: I 1; V B 2,3.)
- Leahy, M. (1936) The Central Highlands of New Guinea, Geog. Jour., 87:229-267. (378: I 1; V A 1; V B 4.)
- Lee, Y. L. (1961) Some aspects of shifting cultivation in British Borneo, Malay. For, 24, No. 2:102-109. (375: I 2; III F 1; III G 0; V A 3.)
- Nieuwenhuis, A. W. (1904; 1907) Quer durch Borneo. Ergebnisse seiner Reisen in den Jahren 1894, 1896-7, und 1898-1900...., E.J. Brill, Leiden, Pt. I, 1904, 493 pp.; Pt. II, 1907, 557 pp. (375: I 1; IV D 3b; V A 3; V B 2.)
- Verstappen, H. Th. (1964) The geomorphology of Sumatra, Jour. of Trop. Geog., 18:184-191. (372: I 3; IV C 0.)
- Withington, William A. (1964) Personal communication. (372: I 1; II A 1; III A 0.)
- Withington, William A. (1963) The distribution of population in Sumatra, Indonesia, 1961, Jour. of Trop. Geog., 17:202-212. (372: I 3; IV C 2; V A 0.)

Australia & Oceania

- Anell, Bengt (1960) Hunting and trapping methods in Australia and Oceania, Studia Ethnographica Upsaliensia, 18, 130 pp. (400: I 1; V B 3.)
- C. W. Thornthwaite Associates (1963) Average climatic water balance data of the continents, Part IV: Australia, New Zealand, and Oceania, Publications in Climatology, 16, No. 3:383-476, C.W. Thornthwaite Associates, Laboratory of Climatology, Centerton, New Jersey. (400: I 4; IV A 0,1.)
- Anonymous (1957) Fire behavior studies, Rep. For. Timb. Bur. Aust 1956, p. 21. (450: I 4; II B 3; IV A 2.)

- Anonymous (1947) Forest fires, Unasylva, 1, No. 3:48-49.
(450: I 0; II B 2,3; IV A 0; V B 1.)
- Anonymous (1957) Ashbed effect, Rep. For. Dep. N. Aust., 1956/1957, pp. 22-24. (450: I 3; III G 0,1; IV C 3; IV D 3b.)
- Badcock, W. J. (1946) Agriculture in the British Solomon Islands Protectorate, Agric. Jour. of Fiji, 17:6; et seq. (420: I 3; III B 0; V A 2.)
- Barnett, H. G. (1949) Palauan Society: A study of contemporary native life in the Palau Islands, University of Oregon, Eugene, Oregon, 223 pp. (430: I 3; V A 3.)
- Barrau, Jacques (1956) Le milieu et l'agriculture traditionnelle en Mélanésie, Annales de Géographie, 65:362-382. (420: I 1; IV D 1,3b; V B 2.)
- Barrau, Jacques (1955) Subsistence agriculture in Melanesia, South Pacific Commission, Noumea, New Caledonia, 189 pp. (Later edition - 1958 - issued as Bernice Paushi Bishop Museum Bull. #219.) (mimeo.) (420: I 3; III B 0; III E 0; IV D 0,1,3b; V A 3; V B 1,2,4.)
- Barrau, Jacques (1959) The "bush fallowing" system of cultivation in the continental islands of Melanesia, Proc. Ninth Pacific Science Congress of the Pacific Science Association 1957, 7:53-55. (420: I 3; V A 0; V B 0,1,2.)
- Bascom, William R. (1948) Subsistence farming on Ponape, New Zealand Geog., 5:115-129. (430: I 1; III B 0; V A 3; V B 1,2.)
- Beadle, N. C. W. (1940) Soil temperatures and their effect on the survival of vegetation, Jour. of Ecol., 28:180-192. (450: I 4; II A 2; III B 0.)
- Bentzen, Conrad (1949) Land and livelihood on Mokil, Part II, C.I.M.A., Office of Naval Research and Nat. Acad. Sci., Washington. Report, No. 25, 188 pp. (mimeo.). (430: I 1; V A 3.)
- Buck, Peter H. (Te Rangī Hiroa) (1938) Ethnology of Mangareva, Bernice P. Bishop Museum, Bulletin 157, The Museum, Honolulu, 519 pp. (440: I 1; IV C 0,3.)
- Burcham, L. T. (1948) Observations on the grass flora of certain Pacific islands, Contr. U.S. Nat. Herb., 30:405-447. (420: I 2; IV C 3; IV D 0,1.)
- Burrows, Edwin G. (1937) Ethnology of Uvea (Wallis Island), Bernice P. Bishop Museum, Bulletin 145, The Museum, Honolulu, 176 pp. (440: I 2; IV D 2; V A 3.)

- Cameron, R. J. (1964) Destruction of the indigenous forests for Maori agriculture during the 19th century, New Zealand Jour. of Forestry, 9, No. 1:98-109. (400: I 2; III G 0,1.)
- Campbell, M. (1961) Burning aids in control of serrated tussock, Department of Agriculture, Sydney, 2pp. (450: I 2; V B .)
- Chippendale, G. M. (1963) Ecological notes on the "Western Desert" area of the Northern Territory. Proc. Linn. Soc. N.S.W., 88:54-66. (450: I 2; III E 0,1; IV A 0,1,2; IV D 1.)
- Clarke, R. H. (1958) Midsummer diurnal winds in the south-east of S. Australia, Fire Weather Conference, Melbourne, Australia, July 1958, Proceed., No. 14, 19 pp. (450: I 3; II A 2; IV A 2; IV B 0.)
- Cochran, G. R. (1963) A physiognomic vegetation map of Australia, Jour. of Ecol., 51:639-655. (450: I 2; IV D 1.)
- Cochrane, R. G. (1963) Vegetation studies in forest-fire areas of the Mount Lofty Ranges, South Australia, Ecology, 44:41-52. (450: I 4; III E 2.)
- Cromer, D. A. N. (1951) Fire weather forecasting in Australia, United Nations Sci. Conf. Conserv., Proc., 5:53-55. (400: I 1; III E 0; IV A 0,1; IV B 0, V B 1.)
- Davis, Charles M. (1959) Fire as a land use tool in north-eastern Australia, Geog. Rev., 49:552-560. (450: I 2; III B 0; IV A 0,3; IV D 0,3b; V B 0,1,3.)
- Derrick, R. A. (1951) The Fiji Islands, Government Printing Department. Suva, Fiji, 334 pp. (420: I 1; IV D 1.)
- Douglas, D. R. (1957) Forest fire weather studies in South Australia, Bull. Wds. For. Dept. S. Aust., 9, 55 pp. (450: I 3; IV A 2; IV D 3b; V B 1.)
- Douglas, D. R. (1964) Some characteristics of major fires in coniferous plantations, Austral. For., 28, No. 2:119-224. (450: I 4; II B 1,2,3,4; III A 2,4; V B 1.)
- Dugain, François (1953) Dégradation et protection des sols de la Nouvelle-Calédonie, Institut Français d'Océanie, Noumea, 20 pp. (420: I 1; III A 0; III F 0; IV C 3.)
- Dugain, François (1953) Premiers observations sur l'érosion en Nouvelle-Calédonie, L'Agron. Tropicale, 8:466-475. (420: I 3; IV C 3; IV D 0,1.)
- Fiji (1958) Fire resistance of slash pine, Rep. For. Dept. Fiji 1957, p. 7. (400: I 3; IV D 1,3b.)

- Foley, J. C. (1947) A study of meteorological conditions associated with bush and grass fires and fire protection strategy in Australia, Met. Bureau Bulletin, No. 38, n.p. (450: I 3; IV A 0,1,2; IV B 0; V B 1.)
- Fosberg, F. R. (1959) The vegetation of Micronesia, Pt. I: General descriptions, the vegetation of the Marianas Islands, and detailed consideration of the vegetation of Guam, Bull. Amer. Mus. Nat. Hist., 119, No. 1, 75 pp. (430: I 4; IV D 2.)
- Green, B. and R. C. Hagerstrom (1964) Experiment in fire protection - the Wandilo Project, Jour. So. Aust. Dept. Agr., 67, No. 6:184-191. (400: I 2; II A 2; IV A 2.)
- Harris, A. C. and W. R. Wallace (n.d.) Controlled burning in Western Australian Forest Reserves, C.S.I.R.O. Research Section, 8 pp. (mimeo.) (450: I 3; II B 0,2,3; IV A 0,2; V A 3; V B 1; V C 1.)
- Harwood, L. W. (1950) Observations on indigenous systems of agriculture, Agric. Jour. of Fiji, 21:1-7. (440: I 1; II A 2; IV D 3b; V B 0,2.)
- Hatch, A. B. (1959) The effect of frequent burning on the jarrak (Eucalyptus marginata) forest soils of West Australia, Jour. Royal Soc. West Africa, 42, No. 4:97-100. (450: I 2; III D 0,2; V B 1.)
- Hogan, J. (1952) Fire hazard forecasts for farmlands, Jour. West. Aust. Dept. Agr., 3, No. 1:603-607. (450: I 1; II B 0; V B 1.)
- Hogbin, Herbert Ian (1939) Experiments in civilization: the effects of European culture on a native community of the Solomon Islands, George Routledge and Sons, London, 268 pp. (420: I 3; II A 0; V B 2.)
- Hogbin, Herbert Ian (1937) The hill people of north-eastern Guadalcanal, Oceania, 8:62-89. (430: I 3; II A 0; V A 3; V B 2.)
- Holland, A. A. and C. W. E. Moore (1962) The vegetation and soils of the Bollon district in S. W. Queensland, Div. For. Prod. Tech. Pap. For. Prod. Austral., No. 17, 31 pp. (450: I 3; IV C 3; IV D 1.)
- Hosaka, E. Y. (1946) Botanical report, Economic Survey of Micronesia, 13, No. 2:1-68, U.S. Commercial Company, Honolulu. (430: I 4; III E 3; IV D 1,2,3,3b.)
- Ivens, W. G. (1927) Melanesians of the South-east Solomon Islands, Kegan Paul, Trench, Trubner and Co., London, 529 pp. (420: I 2; V A 3; V B 0.)

- Jacobs, M. R. (1956) Eucalypt woodland in Australia - background factors influencing occurrence and treatment, Unasylva, 10, No 3:111-115. (400: I 2; III E 0,1; III G 0.)
- Larkins, A. W. (1958) The effect of wind changes on fires, Fire Weather Conference, Melbourne, Australia, July 1958, Proceed., No. 5, 8 pp. (450: I 3; II A 2; II B 0; IV A 0,1,2; IV B 0.)
- Luke, R. H. (1961) Bush fire control in Australia, Hodder and Stoughton, Melbourne, 136 pp. (450: I 4; II B 2,3,4; III E 3; IV A 0,1,2,3; IV B 0,1; IV C 0,1; IV D 0,1,2; V B 1)
- Luke, R. H. (1963) Fire and the conservation of natural resources in New South Wales, Jour. Soil Conserv. Serv. N.S.W., January 1963:37-45. (450: I 3; II A 1; II B 0,1; III E 0; IV A 0; IV B 0; IV D 3b.)
- Luke, R. H. (1960) Meeting protection objectives in difficult years, Fifth World Forestry Cong. 1960, Proc., Session D, pp. 971-975. (450: I 3; IV A 0,1,2,3,4; V B 0.)
- Luke, R. H. (1960) Recent fire protection developments in New South Wales, C.S.I.R.O. Research Section. pp. 14-18. (450: I 3; II B 3.)
- Luke, R. H. (n.d.) The bush fire problem in Australia, C.S.I.R.O. Research Section, 7 pp. (mimeo.) (450: I 3; II A 1; II B 0,2,3; IV A 0; V C 1.)
- McArthur, A. G. (1962) Control burning in eucalypt forests, Leaflet no. 80, Forestry and Timber Bureau, Canberra. (450: I 3,4; II B 0,2,3; III B 0; IV A 0,1,2; IV C 0,1; IV D 3b; IV B 1,2; V B 3.)
- McArthur, A. G. (1964) Fire control in Australia, FAO, United Nations, 8 pp. (450: I 4; II A 1; II B 0; III A 0; III B 0; III E 3; IV A 0; IV C 0,3; V B 1.)
- McArthur, A. G. (1961) Fire danger rating tables for annual grasslands, Forestry and Timber Bureau, Annual report for the year 1960, pp. 10-12. (450: I 3; II B 2,3; III A 0,1; IV B 0.)
- McArthur, A. G. (1963) Revised forest fire danger tables, Forestry and Timber Bureau, Annual report for the year ended 1962, pp. 7-8. (450: I 4; II B 2,3,4.)
- McArthur, A. G. and R. H. Luke (1963) Fire behavior studies in Australia, Fire Control Notes, 24, No. 4:87-92. (450: I 2; IV A 4; V B 1.)

- McLaren, A. C. (1959) Propagation of flames in Eucalyptus oil vapour/air mixtures, Austral. Jour. Appl. Sci., 10, No. 3: 321-328. (450: I 4; II B 2; V C 1.)
- O'Donnell, J. (1939) Forest fire control in Western Australia, Austral. For., 4:15-21. (450: I 2; II B 0; V B 1.)
- Osborn, T. G. B., J. G. Wood and T. B. Paltridge (1935) On the climate and vegetation of the Koonamore Vegetation Reserve to 1931, Proc. Linn. Soc. of N.S.W., 60:392-427. (450: I 2; III E 0,1; IV A 0,1,2; IV C 3; IV D 1.)
- Phillips, Walter S. (1962) Fire and vegetation of arid lands, Tall Timbers Fire Ecology Conference, First annual, Proceed. pp. 81-93. (400: I 3; III E 1; III G 0; IV C 1,3; IV D 0; V B 1.)
- Pitman, E. B. (1947) Bush fire control, Jour. So. Austral. Dept Agr., 51:32. (450: I 1; IV B 0; V B 1.)
- Prior, K. W. (1958) The Balmoral forest fire, New Zealand Jour. of Forestry, 7, No. 5:35-50. (400: I 2; II A 0,1; II B 0,1,2,4,5; IV B 0.)
- Rainbird, A. F. (1958) The problem of wind in the prevention and control of bush fires, Fire Weather Conference, Melbourne Australia, July 1958, Proc., No. 6, 12 pp. (450: I 3; IV B 0.)
- Roberts, W. B. (1964) Temperature profiles under a eucalypt forest canopy, Aust. For. Res. 1. No. 1. n.p. (450: I 3; II B 2; IV C 3.)
- Robin, A. G. (1957) Weather conditions associated with the Broadford fire, Austral. Meteorological Mag., Melbourne, 18:30-43. (450: I 2; II B 3)
- Robin, A. G. and G. U. Wilson (1958) The effect of meteorological conditions on major fires in the Riverina (New South Wales) district, Austral. Meteorological Mag., Melbourne, 21:49-75. (450: I 3; IV A 1,2,3; IV B 1,2.)
- Ridley, W. F. and A. Gardner (1961) Fires in rain forest, Austral. Jour. Sci., 23:227-228. (400: I 2; III E 0,1; III G 0.)
- Sleumer, H. (1955) Proteaceae, Flora Malesiana 5:147-206. (420: I 3; III E 0,2,3; III G 0,1.)
- Smith, C. M. and A. W. Wastney (1935) Forest protection against pastoralists' fires, New Zealand Jour. of Forestry, 3, No. 5:199-203. (400: I 2; II B 2; IV D 3b; V C 1.)
- Specht, R. L. and P. Rayson (1957-1958) Dark island heath (90 mile plain - So. Australia), Pt. III: The root systems, Austral. Jour. Bot., 5-6:103-114. (450: I 4; II B 0; IV D 3b.)

- Specht, R. L., Rayson and H. Jackman (1958) Dark island heath (90 mile plain - So. Australia), VI: Pyric succession: changes in composition, coverage, dry weight and mineral nutrient status, Austral Jour. Bot., 6, No. 1:59-88. (450: I 4; III B 0; IV A 3, IV D 3b.)
- Staner, P. (1940) L'effet du feu sur la température du sol et sur la végétation, Bull. Agric. Congo Belge, 31, No. 1-4:161. (450: I 4; II A 2; III B 0.)
- Stocker, G. C. (n.d.) Notes on the occurrence and effects of vegetation burning in the Northern Territory, (Manuscript, in press), 18 pp. (450: I 3; II A 2; II B 0,4; III E 0,1,2,3; III F 0; III G 0; IV B 0; IV C 0; IV D 0, 1,2; V A 3; V B 1,2,3,4; V C 0,1.)
- Thomson and K. W. Prior (1958) Natural regeneration of P. radiata following the Balmoral forest fire, New Zealand Jour. of Forestry, 7, No. 5:51-70. (400: I 3; III E 0,1.)
- Torbet, E. R. (1952) Fire protection in Victoria, Australia, Government Printer, Melbourn 15 pp. (450: I 3; II B 0; V B 1)
- Ward, R. Gerard (1960) Village agriculture in Viti Levu, Fiji, New Zealand Geog., 16, No. 1:33-56. (420: I 3; II A 2; III G 0; IV C 0,3; IV D 1; V A 0,3; V B 0,1,2,4.)
- Watters, R. F. (1960) Some forms of shifting cultivation in the southwest Pacific, Jour. of Trop. Geog., 14:35-50. (420: I 2; III G 0,1; V A 2,3.)
- Western Australia Soil Conservation Service (1963) Fire-breaks without erosion, West Austral. Dept. Agr. J., 4, No. 11:710-712, 715-717. (400: I 2; V B 1.)
- Whittingham, H. E. (1965) A review of fire weather investigations in Australia, Fire Research Abstracts and Reviews, Nat. Acad. Sci., NRC, 7, No. 1:19-26. (450: I 3; III E 3; IV B 0; IV D 3b.)
- Whittingham, H. E. (1958) Meteorological factors controlling success or failure of scrub burning in plantation areas in southeast Queensland, Fire Weather Conf., Melbourne, Australia, July 1958, Proc., No. 4, 40 pp. (450: I 3; II A 2; II B 0,1; IV A 0,1,2,3; V B 0,1,3.)
- Whittingham, H. E. (1958) The behavior of the sea breeze in the forest areas of southeast Queensland, Fire Weather Conference, Melbourne, Australia, July 1958, Proc., No. 15, 40 pp. (450: I 4; IV B 0.)
- Wilson, G. U. (1958) A capability study of forecasts of maximum temperature, relative humidity, dew point, wind and precipitation in several states with special application to fire weather requirements, Austral. Meteorological Mag., Melbourne, 21:31-48 (450: I 4; IV A 1.)

Wilson, G. U. (1958) Some problems of estimating and predicting moisture content of forest and grass fuels, Fire Weather Control, Melbourne, Australia, July 1958, Proc., No. 3, 9 pp. (450: I 4; II B 4; III E 3; IV C 3.)

North America

Ahlgren, I. F. and C. E. Ahlgren (1965) Effects of prescribed burning on soil microorganisms in a Minnesota Jackpine forest, Ecology 46, No. 3:304-310. (500: I 4; II B 2; III D 0,3.)

Anderson, L. King (1964) Burning Flint Hills bluestem ranges, Tall Timbers Fire Ecology Conference, Proc., Third Annual Conf., 1964, pp. 89-102. (500: I 3; II A 1; III A 0; III B 0; V A 3.)

Beaufait, William R. (1961) Crown temperatures during prescribed burning in jack pine, Papers Michigan Acad. Science, Arts and Letters, Part I: Natural Science, 46: 251-257. (500: I 4; II B 1,2; IV A 0.)

Bernard, J. M. (1963) Forest floor moisture capacity of the New Jersey pine barrens, Ecology, 44, No. 3:574-576. (500: I 3; III D 0,1,2.)

Biswell, H. H., B. L. Southwell, J. W. Stevenson, and W. O. Shephard, (1942) Forest grazing and beef cattle production in the coastal plain of Georgia, Ga. Coastal Plain Exper. Sta. Circ., No. 8, 25 pp (500: I 2; II A 2; II B 0; V B 2.)

Biswell, H. H. (1963) Research on wildland fire ecology in California, Tall Timbers Fire Ecology Conference, Proc. Second Annual Conf., 1963, pp. 63-97. (500: I 4; II A 1; II B 0; III A 0; IV A 3; IV C 0; IV D 0.)

Burgy, R. H. and V. H. Scott (1953) Discussion of "Some effects of fire and ash on the infiltration capacity of soils," Trans. Amer. Geophys. Union, 34, No. 2:293-295. (500: I 4; III C 0; III D 2.)

Burgy, R. H. and V. H. Scott (1952) Some effects of fire and ash on the infiltration capacity of soils, Trans. Amer. Geophys. Union, 33, No. 3:405-416. (500: I 4; II B 3; III B 0.)

Cooper, C. F. (1961) The ecology of fire, Sci. Amer., 204, No. 4:150-156, 158, 160. (500: I 1; III A 0; V B 2.)

Cooper, Robert W. (1962) Is prescribed burning paying off? Tall Timbers Fire Ecology Conference, Proc. First Annual Conf., 1962, pp. 145-150. (500, 600: I 4; II B 3; III A 0; III B 0; III E 3; IV A 3.)

- Cooper, R. W. (1963) Knowing when to burn, Tall Timbers Fire Ecology Conference, Proc. Second Annual Conf., 1963, pp. 31-34. (500: I 3; II B 0; V B 0.)
- Countryman, C. M. and M. J. Schroeder (1958/1959) Prescribed burn fireclimatic survey 1-57, Tech. Papers No. 29 (1958), No. 31 (1959), No. 34, 35 (1959), U.S. For. Service, Calif. For. and Range Exper. Station. (500: I 4; III B 0; IV B 0; IV C 0, 3.)
- Cypert, E. (1961) The effects of fires in the Okefenokee Swamp in 1954 and 1955. American Midland Nat. 66, No. 2: 485-503. (500: I 2; II A 1; II B 0, 1, 2, 5; III D 0; III E 0, 1; III G 0.)
- Day, G. M. (1953) The Indian as an ecological factor in the northeastern forest, Ecology, 34:326-346. (500: I 1; III G 0.)
- Dyksterhuis, E. J. (1957) The savanna concept and its use, Ecology, 38:435-442. (500: I 3; IV D 0.)
- Fahnestock, G. R. and R. C. Hare (1964) Heating of tree trunks in surface fires, Jour. of For., 62, No. 11:799-805. (500: I 4; II B 2, 3; III G 0.)
- Folweiler, A. D. (1937) Theory and practice of forest fire protection in the United States, Louisiana State University, Baton Rouge, 164 pp. (500: I 2; V B 1.)
- Folweiler, A. D. (1938) Forest fire prevention and control in the United States, Louisiana State University, Baton Rouge. (500: I 2; V B 1.)
- Halls, L. K., B. L. Southwell and F. E. Knox (1952) Burning and grazing in coastal plain forests, Ga. Coastal Plain Exp. Sta., No. 51, 33 pp. (500: I 2; III E 0, 1; III G 0.)
- Heyward, F. D. (1936) Soil changes associated with forest fires in the long leaf pine region of the South, Amer. Survey Assoc. Bull. (Proc. 16th Annual Meeting), 17:41-42. (500: I 4; III D 0, 1, 2.)
- Heyward, F. D. (1938) Soil temperatures during forest fires in the longleaf pine region, Jour. of For., 36:478-491. (500: I 4; II B 2.)
- Heyward, F. and A. N. Tissot (1936) Some changes in the soil fauna associated with forest fires in the longleaf pine region, Ecology, 17:659-666. (500: I 3; III D 3.)
- Horton, J. S. and C. J. Kraebel (1955) Development of vegetation after fire in the Chamise chaparral of Southern California, Ecology, 36:244-262. (500: I 4; III E 0, 1.)

- Humphrey, Robert R. (1958) The desert grassland: a history of vegetational change and an analysis of causes, Bot. Rev., 24, No. 4:193-252. (500: I 0; III E 0,1; III G 0.)
- Humphrey, Robert R. (1963) The role of fire in the desert and desert grassland areas of Arizona, Tall Timbers Fire Ecology Conference, Proc. Second Annual Conf., 1963, pp. 45-61. (500: I 4; IV D 3b.)
- Kay, B. L. (1960) Effect of fire on seeded forage species, Jour. of Range Management, 13, No. 1:31-33. (500: I 2; IV D 3b.)
- Kollmorgen, Walter M. and David S. Simonett (1965) Grazing operations in the Flint Hills-Bluestem pastures of Chase County, Kansas, Annals, A.A.G., 55, No. 2:287-288. (500: I 4; III B 0; III G 0,1.)
- Kruger, D. W. (1961) Threshold values of relative humidity for large fires in Georgia, Georgia Forest Res. Council, Georgia For. Res. Paper, No. 3, 5 pp. (500: I 4; III A 0; IV A 0,1,4.)
- Martin, Robert E. (1962) A basic approach to fire injury of tree stems, Tall Timbers Fire Ecology Conference, Proc. First Annual, 1962, pp. 151-162. (500, 600: I 4; II B 2; III B 0.)
- McNasser, K. W. (1963) The team approach to forest fire research, Tall Timbers Fire Ecology Proc. Second Annual Conf., 1963, pp. 127-133. (500: I 3; II B 0; V B 0.)
- Reynolds, H. G. and J. W. Bohning (1956) Effects of burning on a desert grass-shrub range in southern Arizona, Ecology, 37:769-777. (500: I 4; III E 0,1.)
- Robertson, William B. (1962) Fire and vegetation in the Everglades, Tall Timbers Fire Ecology Conference, First Annual, 1962, pp. 66-80. (500: I 3; II A 2; III B 0; III G 0; IV A 1; IV B 0; IV C 2; IV D 1,3b.)
- Schroeder, M. J. (1961) Down canyon afternoon winds, Bull. Amer. Meteor. Soc., 42, No. 8:527-542. (500: I 3; IV B 0.)
- Schroeder, M. J. and C. M. Countryman (1960) Exploratory fireclimate surveys on prescribed burns, Monthly Weather Review, 88(4):123-129. (500: I 4; II A 2; III A 2,4; IV A 2,3; IV B 0.)
- Stoddard, Herbert L. Sr. (1962) Some techniques of controlled burning in the deep Southeast, Tall Timbers Fire Ecology Conference, First Annual, 1962, pp. 133-144. (500, 600: I 4; II A 1; V B 0.)

- Sweeney, J. R. (1956) Responses of vegetation to fire: a study of the herbaceous vegetation following chaparral fires, Univ. of Calif. Publ. in Bot., 28:143-250. (500: I 3; III D 1.2; III E 0.1.)
- Tarrant, R. (1956) Effect of slash burning on some physical soil properties, For. Sci., 2:18-22. (500: I 3; III D 2.)
- Wright, H. A. and J. O. Klemmedson (1965) Effect of fire on bunch grasses of the sagebrush-grass region in southern Idaho, Ecology, 46, No. 5:680-688. (500: I 4; III E 0.)

Non-Regional

- Ahlgren, I. F. and C. E. Ahlgren (1960) Ecological effects of forest fires, Bot. Rev., 26, No. 4:483-533. (600: I 3; II B 2; III A 1; III C 0; III D 0,2,3; III E 0.)
- Barrows, J. S. (1961) Natural phenomena exhibited by forest fires, in: The use of models in fire research, Berl, W.G. (ed.). Publication 786, The Fire Research Conference, Nov. 9-10, 1959, Nat. Acad. Sci., NRC, Washington, D.C., pp. 281-288. (600: I 2; II B 3.)
- Berl, W. G. (ed.) (1961) The use of models in fire research, Publication 786, The Fire Research Conference, Nov. 9-10, 1959, Nat. Acad. Sci., NRC, Washington, D.C., 321 pp. (600: I 4; II B 2,3.)
- Budowski, Gerardo (1958) Climatologia, Inst. Interamericano de Ciencias Agricolas, Turrialba, Costa Rica, 12 pp., (mimeo.). (600: I 3; IV B 2.)
- Byram, G. M. (1958) Some basic thermal processes controlling the effects of fire on living vegetation, Research Notes, South Eastern For. Exp. Sta., No. 114, 2 pp. (600: I 4; II A 2; IV D 3b.)
- Bryam, George M. (n.d.) Some principles of combustion and their significance in forest fire behavior, USDA Forest Service, Fire Control Notes, 18, No. 2:47-57. (600: I 4; II B 0.)
- Charlton, F. G. (1964) Standard catchments in the estimation of flood flows, Jour. of Trop. Geog., 18:43-53. (600: I 4; IV C 2.)
- Ching, F. F. T. and W. S. Stewart (1962) Research with slow burning plants, Jour. of For., 60, No. 11:796-798. (600: I 4; II B 3,5; V B 1.)
- Countryman, C.M. (1960) Fire environment and silviculture practice, Soc. Amer. Foresters, Proc., pp. 22-23. (600: I 2; II B 2,3; III A 2,3,4; IV B 0,2; V B 1.)

- Davis, K. P. (1959) Forest fire control and use, McGraw-Hill, N.Y., 584 pp. (600: I 4; II B 0,1,2; III A 1,4; III B 0,1; III C 0,1; III D 0,1,2,3; III E 0,1; III G 0; IV A 0,1,2,3,4; IV B 0,1,2; IV D 0,1; IV D 3a,c; V B 1,3; V C 0,1.)
- DeHaven, James (1957) A commentary on fire research, in: Methods of studying mass fires, Publication 569, Second Fire Research Correlation Conference, May 26-28, 1957, Nat. Acad. Sci., NRC, Los Angeles, California, pp. 10-12. (600: I 3; II B 3; III B 0; III F 0,2; IV D 3b.)
- Edwards, D. C. (1942) Grass-burning, Emp. Jour. Exp. Agric., 10:219-231. (600: I 2; III D 0,1,2; III E 0; III G 0; V B 1.)
- Forestry Commission (1963) Report on fire research for the year ended March, 1962, Her Majesty's Stationery Office, London, 194 pp. (600: I 4; II B 3.)
- Hare, R. C. (1961) Heat effects on living plants, U.S. Forest Service, Southern Forest Experiment Station, Occasional paper, No. 183, 32 pp. (600: I 4; III E 0.)
- Holdridge, L.R. (1959) Simple method for determining potential evapotranspiration from temperature data, Inter-American Institute, Turrialba, Costa Rica, 2 pp. (mimeo.). Reprinted from Science 130, No. 3375:572. (600: I 4; IV A 0.)
- Kivekas, J. (1941) Influence of shifting cultivation, with burning, upon some properties of the soil, Soils and Fertilizers, 4:194. Also in: Commun. Inst. Forest. Fenniae, 27:44. (600: I 2; III D 0,1,2.)
- Klemmedson, J. O., A. M. Schultz, H. Jenny, et al. (1962) Effect of prescribed burning of forest litter on total soil nitrogen, Soil Sci. Soc. Amer., Proc., 26:200-202. (600: I 4; III D 1,2.)
- Komarek, E. V. Sr. (1964) The natural history of lightning, Tall Timbers Fire Ecology Conference, Third Annual, April 9-10, 1964, pp. 139-173. (600: I 3; II B 2.)
- Le Borgne, E. and G. Monnier (1959) Influence du feu sur certaines propriétés du sol, C. R. Acad. Sci., 248, No. 10: 1549-1551. (600: I 3; II B 1.)
- Martin, Robert E. and Lawrence S. Davis (1961) Temperatures near the ground during prescribed burning, Papers of the Michigan Acad. of Science, Arts and Letters, Part I: Natural Science, 46:239-249. (600: I 4; II B 2; III A 0; IV A 0,1.)
- Morton, B. R. (1964) Fire and wind, Sci. Prog., (London), 52, No. 206:249-258. (600: I 3; IV B 0.)

- Murgai, M. P. and H. W. Emmons (1960) Natural convection above fires, Journal of Fluid Mechanics, London, 8, No. 4: 611-24. (600: I 4; II B 2.)
- National Academy of Sciences, (1961) A study of fire problems, Committee on Fire Research, Publication 949, A study held at Woods Hole, Mass., July 17-Aug. 11, 1961, Nat. Acad. Sci., NRC, Washington. D.C., 176 pp. (600: I 3; II B 0,1,3,4; III A 0,2; III D 1; IV A 0,1,2; IV B 0,1,2; V B 1.)
- National Academy of Sciences (1958) Methods of studying mass fires, Committee on Fire Research and Fire Research Conference, Publication 569, Second Fire Research Correlation Conference, May 26-28, 1957, Nat. Acad. Sci., NRC, Los Angeles, California, 48 pp. (600: I 4; II B 0,2; IV A 2; IV B 1.)
- Reifsnyder, William E. (1965) Symposium on forest fire research at Tenth Pacific Science Congress--University of Hawaii, August 31, 1961, Fire Research Abstracts and Reviews, 7. No. 2:73-75. (600: I 3; II B 0,1,2,3; IV A 0,1; V B 1.)
- Reifsnyder, W. E. (1962) Weather and fire control practices, Fifth World Forestry Congress, 1960, Proc., No. 2:835-841. (600: I 3; II B 0; III A 2,3; IV A 3; IV C 3.)
- Sampson, A. W. (1944) Effect of chaparral burning on soil erosion and on soil moisture relations, Ecology, 25:171-191. (600: I 2,3; III B 0.)
- Sargent, Frederick and W. Henson (1961) Bioclimatology (Second Scientific Congress of the International Society of Bioclimatology and Biometeorology, London, Sept. 1960), Science, Wash., D.C., 133, No. 3453:650-651. (600: I 1; IV A 0,1,2.)
- Thomas, P. H. and Roberta Scott (1963) Research on forest fires, in: Report on forest research for the year ended March, 1962, Forestry Commission, Her Majesty's Stationery Office, London, pp. 116-118. (600: I 4; II B 3.)
- Thomas, P. H. and R. W. Pickard (1961) Fire spread in forest and heathland materials, in: Report on Forest Research for the year ended March 1961, pp. 105-108. (600: I 4; II B 1,2,3,4,5.)
- United States Weather Bureau, Office of Climatology and Division of Oceanography (1959) Climatological and oceanographic atlas for mariners, Vol. I: North Atlantic Ocean, U.S. Department of Commerce, Weather Bureau, U.S. Government Printing Office, Washington, D.C., n.p. (600: I 4; IV A 0,1,2,3.)

Whittaker, Edith (1961) Temperatures in heath fires, Jour. of Ecol., 49:709-715. (600: I 4; II B 2,3; IV A 2; V B 2.)

Addendum

Countryman, C. M. (1964) Mass fires and fire behavior, Forest Service Research Paper, PSW-19, (Pacific Southwest Forest and Range Experiment Station, U.S. Forest Service Berkeley, California). (500, 600: I 4; II A 0; III A 0,1,2; III B 0,1; IV A 0,1,2; IV B 0,1,2.)

Edwards, D. C. (1942) Grass burning, Emp. Jour. of Exp. Agric., 10:219-231. (172: I 4; II A 2; III D 0,1,2,3; III E 0,1,2,3; III F 0; IV D 0,1,2; V A 3.)

Fahnestock, G. R. and R. C. Hare (1964) Heating of tree trunks in surface fires, Jour. of For., 62:799-805. (500, 600: I 4; II A 0; II B 2,3,4; III E 0.)

Gardner, T. A. M. (1965) Extracts from Forest Department Annual reports 1945-63. (Forest Department, Ministry of Natural Resources and Wildlife, Nairobi), 9 pp., (typescript). (172: I 3; II A 0; II B 0,1,2; IV B 0; V B 2.)

Glover, Harold (1951) A tour in Latin America, Chapter II, Peru, 4th May to 30th May, 1950, Empire Forestry Review, 30:149-155. (261: I 1; II B 1; V C 1.)

Haantjens, H. A., J. A. Mabbutt and R. Pullen (1965) Anthropogenic Grasslands in the Sepik Plains, New Guinea, Pacific Viewpoint, 6, No. 2:215-219. (378: I 3; III D 2.)

Hoehne, Federico Carlos (1914) Expedição Scientifica Roosevelt-Rondon, Anexo no. 2 Botanica, Rio de Janeiro. (241: I 2; IV D 0,1,3b; V A 3.)

Hoehne, Federico Carlos (1916) Relatorios dos Trabalhos de Botanica e Viagens executados durante os annos de 1908 e 1909, Comissao de Linhas Telegraficas Estrategicas de Matto-Grosso ao Amazonas Publicacao n. 28, Anexo n.4, Rio de Janeiro. (241: I 2; IV D 0.)

Kelly-Edwards, F. J. (1937) Veld fires, Rhodesia Agric. Jour., 34:241-248. (177: I 2; V B 1.)

Langdale-Brown, I. (1960) The vegetation of Uganda (excluding Karamoja), Memoirs of Res. Div., No. 6, 45 pp., Uganda Dept. of Agriculture. (174: I 4; IV A 0,1; IV C 2; IV D 2.)

Lea, D. A. M. (1965) The Abelam: A study in local differentiation, Pacific Viewpoint, 6, No. 2:191-214. (378: I 3; V A 3.)

Miracle, Marvin P. (1964) Traditional agricultural methods in the Congo Basin, Food Research Institute, Stanford University, California, 219 pp. (125, 145: I 3; II A 0,2; V A 0; V B 2.)

Pelzer, Karl J. (1945) Pioneer settlement in the Asiatic Tropics: studies in land utilization and agricultural settlement in Southeastern Asia, Chapter II, "The Shifting Cultivator." pp. 16-34. New York: American Geographical Society, 290 pp. (350, 360: I 4; III E 1; III F 0; III G 0; V A 3; V B 0,1,2; V C 0.)

Phillips, John (1965) Fire--as master and servant: its influence in the bioclimatic regions of trans-Saharan Africa, Fourth Annual Tall Timbers Fire Ecology Conference, Proc., 1965, Tall Timbers Research Station, Tallahassee, Florida, 279 pp. (100: I 3; II B 0,2; III A 0,1,2; III D 0,1,2,3; III E 0,1.)

Suarez de Castro, Fernando (1957) Las quemas como practica agricola y sus efectos, Federacion Nac. de Cafeteros de Colombia Boletin Tecnico 2.18:1-21, Chinchina, Caldas, Colombia. (250: I 4; III B 0,1; III D 0,1,2,3.)

SECTION II

Tropical World

Aubreville, A. (1954) Feux de brousse et microbiologie du sol Bois et Forêts Trop. 34, Mars-Avril, p. 49. (000)

Baldanzi, G. (1959) Il fuoco come strumento nell'agricoltura tropicale, Proc. World Congr. Agric. Res., pp. 1189-1197. (000)

Beard, J. S. (1963) Ecosystems and biological productivity of savanna, 9th tech. Mtg. Int. Union Conserv. Nature, Nairobi, 1963, Papers, 7 pp. (000)

Bedard, Paul W. (1960) Shifting Cultivation - Benign and Malignant Aspects, Proc. 5th World Forestry Congress, Seattle, 1960, Vol. 3, pp. 2016-2020. (000)

Beirnaert, A. (1941) La technique culturale sous l'equateur. I: influence de la culture sur les reserves en humus et en azote des terres equatoriales, Bruxelles, Institut National pour l'Etude Agronomique du Congo Belge, Ser. techn., No. 26, 86 pp. (000)

Blaut, James M. (1959) The ecology of tropical farming systems, in: Plantation systems of the New World, Pan American Union, Washington, Social Science Monographs 7, pp. 83-97. (000)

- Carneiro, Robert (1960) Slash-and-burn agriculture: a closer look at its implications for settlement patterns, in: Men and cultures (Anthony F. C. Wallace, ed.), Selected paper of the Fifth International Congress of Anthropological and Ethnological Sciences, Philadelphia, 1956, pp. 229-234. (000)
- Conklin, Harold C. (1959) Population-land balance under systems of tropical forest agriculture, Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association, 1957, 7:60-62. (000)
- Conklin, Harold C. (1961) The study of shifting cultivation, Current Anthropology 2, No. 1:27-61. (000)
- Consigny, A. (1937) L'avenir économique de nos possessions d'Outre-Mer compromis par les feux de brousse, de savane et de forêt, Actes et C. R. Ass. Col.-Sc., 13, No. 141: 50-60, No. 142:73-77. (000)
- Cook, O. F. (1941) Milpa agriculture, Ann. Rept. Smithsonian Inst. for 1919, Washington, pp. 307-326. (000)
- de Schlippe, Pierre (1955) Le nomadisme agricole, problème des régions tropicales humides. Probl. Agr. Centr., 29, No. 3:202-207. (000)
- De Wildeman, E. (1939) Feux de savanes, de brousse ou de forêt Bull. Acad. Roy. Belgique, Classe des Sciences No. 1/4:16-17. (000)
- Fons, W. L. (1946) Analysis of fire spread in light forest fuels, Jour. Agr. Res., 72:93-121 (000)
- Freise, F. W. (1939) Untersuchungen über die Folgen der Brandwirtschaft auf tropischen Boden, Tropenpflanzer, 42:1-22. (000)
- Gray, A. P. (1944) Ecology, in: Imperata cylindrica: taxonomy, distribution, economic significance and control, pp. 18-23, Oxford and Aberystwyth, Imperial Agricultural Bureaux. (000)
- Gray, A. P. (1944) The effect of I. cylindrica on economic crops, in: Imperata cylindrica: taxonomy, distribution, economic significance and control, pp. 24-26, Oxford and Aberystwyth, Imperial Agricultural Bureaux. (000)
- Gray, A. P. (1944) Methods of control, in: Imperata cylindrica: taxonomy, distribution, economic significance and control, pp. 45-53, Oxford and Aberystwyth, Imperial Agricultural Bureaux. (000)
- Haan, J. H. de. (1959) A study of shifting cultivation, Netherlands Journal of Agricultural Science (Nederlands Genootschap voor Landbouwwetenschap), 7:150-154. (000)

- Hewetson, C. E. (1950) Seventy-five years of fire protection in the tropics, Emp. For. Rev., 29:4. (000)
- Holscher, C. E. (1946) Fire as a means of range betterment on brushland, Rec. Stockman, 57, No. 23:7. (000)
- Humbert, H. (1938) Les aspects biologiques du problème des feux de brousse et la protection de la nature dans les zones intertropicales, Inst. Roy. Colon. Belge, Bull. des séances, 9, No. 3:811-835. (000)
- Jeffreys, M. D. W. (1951) Feux de brousse, Bull. IFAN, 13, No. 3:682-710. (000)
- Kellogg, C. E. (1948) Lands of shifting cultivation, in: Soil conservation, F.A.O. Agricultural series, No. 4: 110-129. (000)
- Kellogg, C. E. (1963) Shifting cultivation, Soil Sci., 95: 221-230. (000)
- Laudelout, H. (1954) Etude sur l'apport d'éléments minéraux résultant de l'incinération de la jachère forestière, Deuxième Conf. Interafr. Sols (CCTA), 1:383-388. (000)
- Leclere, A. (1948) Les incendies de forêts, Bois, 65, No. 1: 1. (000)
- Miller, K. G. (1957) The use of aerial photographs in forestry in British Colonies, 7th British Comm. Forestry Conference, London, 1-7. (000)
- Mooney, Herbert Francis (1960) The problem of shifting cultivation with special reference to Eastern India, the Middle East, and Ethiopia, Proc. 5th World Forestry Congress, Seattle, 1960, 3:2021-2025. (000)
- Nye, P. H. and D. J. Greenland (1960) The soil under shifting cultivation, Commonwealth Bureau of Soils, Rothamstead Exp. Sta., Technical Communications, No. 51. (000)
- Ochse, J. J., M. J. Soule, Jr., M. J. Dijkman, and C. Wehlburg (1961) Tropical and subtropical agriculture, New York, Macmillan Co., 2 Vols., 1446 pp. (000)
- Pelzer, Karl J. (1958) Land utilization in the humid tropics: Agriculture, Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association, 1957, 20:124-143. (000)
- Phillips, John F. V. (1962) The development of agriculture and forestry in the tropics: patterns, problems and promise, New York, Praeger, 212 pp. (000)
- Steenis, C. G. G. J. van (1958) Tropical lowland vegetation: the characteristics of its types and their relation to climate, Proceedings of the Ninth Pacific Science Congress of the Pacific Science Association, 1957, 20:25-36. (000)

- Thornthwaite, C. W. (1951) The water balance in tropical climates. Bull. Amer. Met. Soc., 32:166-173. (000)
- Troll, C. (1952) Das Pflanzenkleid der Tropen in seiner Abhängigkeit von Klima, Boden und Mensch, Deutscher Geographentag Frankfurt/Main, 1951, Tagungsberichte und wissenschaftliche Abhandlungen des Deutschen Geographentages, 28:35-66. (000)
- Troll, C. (1952) Local winds in tropical mountains, their influence on precipitation and vegetation (in Ger.), Bonner Geogr. Abhandlungen. Heft 9. (000)
- UNESCO (1962) Symposium on the impact of man on humid tropics vegetation, Goroka, Territory of Papua and New Guinea, September 1960, Administration of the Territory of Papua and New Guinea and UNESCO Science Co-operation Office for S. E. Asia., 402 pp. (000)
- Wagemans, J. (1961) Influence de la protection des feux sur la reforestation naturelle des savanes guinéennes, I.N.E.A.C., 25 pp., (polycop.) (000)
- Wright, A. C. S., and I. T. Twyford (1957) Soil development, shifting cultivation and permanent agriculture in the humid tropics, Agricultural Journal of Fiji 28, No. 3-4: 56-61. (000)

Africa South of the Sahara General

- Allan, William (1945) African land usage, Rhodes-Livingstone Journal (Manchester), June, 1945. (100)
- Barat, C.H. (1956) Les données de la pluviologie dans la zone intertropicale, Bull. Ass. Géog. Fr., No. 261-262: 175-184. (100)
- Bureau Inter africain des Sols (1957) L'Action des feux sur les sols et la végétation, Bull. bibliographique mensuel du BIS, No. 6-7. 27 pp. (100)
- Dundas, J. (1944) Brush burning in tropical Africa, Emp. For. Jour., 23:122-125. (100)
- Lansigan, Nicolas (1954) Investigation on the mineral-element supply by forest-fallow burning, Proceedings of the Second Inter-African Soils Conference 1:383-388. (100)
- Maudoux, Emile A. and G. G. Geortay (1960) La culture nomade en Afrique: Son influence sur les forêts - sa rationalisation son intensification, Proc. 5th World Forestry Congress, Seattle, 1960, 3:2033-2038. (100)
- Phillips, John (1959) Agriculture and ecology in Africa: A study of actual and potential development south of the Sahara. London. Faber and Faber, 424 pp. (100)

Phillips, J. F. V. (1930 and 1931) Fires in African forests, So. Afr. Jour. Sci., 27, also: Mémoires, Bot. Surv. So. Afr. 14. (100)

Worthington, E. B. (1938) Science in Africa: a review of scientific research relating to tropical and southern Africa, London, Oxford University Press, 746 pp. (100)

Western Africa

Bellouard, P. (1951) Rapport fédéral de C'A.O.F., Première Conf. Interafricaine, Abidjan, 1951, pp. 33-120. (130)

Brien, P. (1938) La plaine de Kamolondo, son aspect naturel, sa fauna, ses feux de brousse, Ann. Soc. Roy. Zool. Belg., 69:119-137. (120)

Chevalier, A. (1933 and 1934) Etude sur les prairies de l'Ouest Africain, Rev. Bot. Appl. et Agr. Trop., 13:845-892, 14:17-48, 109-137. (130)

Clarkson, J. R. (1957 and 1958) Seasonal movement of boundary of northern air, British West African Meteor. Services, Toch Notas, No. 5, and Addendum No. 1. (150)

Commission Fédérale de L'Éducation de Base (1954) Les feux de brousse, Dakar, Grande Imprim. Africaine. (130)

De Craane, A. (1947) Les feux de brousse, C. R. Semaine Agric. Yanzambi, 1947, 73:233. (120)

Ekwensi, C. (1962) Burning grass: a story of the Fulani of Northern Nigeria, London. Heinemann Educ. Books, 150 pp. (154)

Forde, Daryll (1953) The cultural map of West Africa: succession adaptations to tropical forests and grasslands, Transactions of the New York Academy of Sciences series 2, No. 15:206-19. (120)

Hamilton, R. A. and J. W. Archbold (1945) Meteorology of Nigeria and adjacent territories, Q.J.R. Met. Soc., 71: 231-264. (154)

Hinds, J. M. (1947) On grass-burning, Farm and Forest, (Nigeria), 8. No. 2:67-71. (154)

Hopkins, Brian (1965) Forest and Savanna: an introduction to tropical plant ecology with special reference to West Africa, Ibadan and London, Heinemann, 1965, 100 pp. (130)

Jaeger, P. (1959) Vers une destruction accélérée de la savane soudanaise, Protection de la Nature, No. 22. (130)

Keay, Ronald W. J. (1952) Some notes on the ecological status of savannah vegetation in Nigeria, Bur. Pasture and Field Crops, Bull. 41:57-68. (154)

- Killian, Ch. (1942) Sols de forêt et sols de savane en Côte d'Ivoire, Ann. Agro., 12:600-632. (134)
- Leneuf, N. and G. G. Aubert (1958) Sur l'étude des savanes en Basse Côte d'Ivoire, Bulletin des sols de l'A.E.F., No. 6. (134)
- MacGregor, W. D. (1937) Forest types and succession in Nigeria, Empire For. Jour. 16:234-242. (154)
- Mensbruge, de la (1958) Rapport sur les résultats obtenus dans les parcelles d'expériences sur les feux de brousse en Côte d'Ivoire, Conférence Interafricaine Forestière, Pointe Noire, 1958, 12 pp. (134)
- Nash, T. A. M. (1960) Fire control in savanna forest reserves, Nigeria Dept. Forest Res., Forest Res. Conf. Proc. 1960, pp. 11-16. (154)
- Pitot, A. and H. Masson (1951) Quelques données sur la température au cours des feux de brousse aux environs de Dakar, Bull. IFAN, 13, No. 3:711-732. (132)
- Prothero, R. M. (1957) Land use, land holdings and land tenure at Soba, Zaria Province, Northern Nigeria, Bulletin de l'Institut Français d'Afrique Noire 19, No. 3:558-563. (154)
- Ramsay, J. M. and R. Rose Innes (1963) Some quantitative observations on the effects of fire on the Guinea savanna vegetation of northern Ghana over a period of eleven years, African Soils, 18, No. 1:41-84. (153)
- Schnell, R. (1944) L'action de l'homme sur la végétation dans la région des monts Nimba et du massif des Dans (A.O.F.), Bull. Soc. Hist. Nat. Afr. Nord., 35:111-116. (130)
- Sly, J. M. A. and P. B. Tinker (1962) An assessment of burning in the establishment of oil palm plantations in southern Nigeria, Tropical Agriculture, 39, No. 4:271-280. (154)
- Wills, J. B., (ed.) (1962) Agriculture and land use in Ghana, London, Oxford Univ. Press, 504 pp. (153)

Central Africa

- Aubréville, A. (1947) Les brousses secondaires en Afrique équatoriale. Côte d'Ivoire, Cameroun, A.E.F., Bois et Forêts des Tropiques, 2:24-35. (140)
- Baxter, P. T. W. and Audrey Butt (1953) The Azande, and related peoples..., in: Forde, Daryll (ed.), Ethnographic survey of Africa, Vol. I, Part 9. (142)

- Biernaux, J. (1954) Une méthode de mise en défense de savanes dans le territoire de Thysville s'appuyant sur la pratique coutumière des "Nkunku", Deuxième Conférence Interafricaine des Sols, Leopoldville, 2:843-66. (125)
- Bervoets, W. and M. Lassance (1959) Modes et coutumes alimentaires des congolais en milieu rural, Brussels, n.p. (125)
- Bourgeois, R. (1957) Banyarwanda et Barundi, Académie Royale des Sciences Coloniales, Classe des Sciences Morales et Politiques, Mém. in-8, Nouvelle série, Tome XV, (fasc. unique). (126, 127)
- Bultot, F. (1957) Risques d'années sèches et pluvieuses au Congo belge et au Ruanda-Urundi, Public Bureau Clim., INEAC. (125)
- Bultot, F. (1957) Saisons et périodes sèches et pluvieuses au Congo belge et au Ruanda-Urundi, Public. Bureau Clim. INEAC. (125)
- Central African Republic, Mission Socio-Economique Centre Oubangui (n.d.) L'emploi du temps du paysan dans une zone de l'Oubangui Central 1959-60, Paris. (143)
- Clement, J. M. (1953) L'agriculture dans le District du Sankuru: Reflexions sur son developpement, Bull. Agric. Congo Belge, April 1953. (125)
- Douglas, Mary (1954) The environment of the Lele, Zaire, Oct. 1954. (125)
- Eeckhout, L. E. (1949) Monographie agricole de la région d'Ikoma (Kivu), Bull. Agric. Congo Belge, Sep.-Dec. 1949. (125)
- Hecq, J. (1958) Le systeme de culture des Bashi (Kivu, Territoire de Kabare) et ses possibilités, Bull. Agric. Congo Belge, August 1958. (125)
- Hecq, J. and A. Lefebvre (1959) Eléments de la production agricole au Bushi (Kivu-Territoire de Kabare), Bull. Agric. Congo Belge, March 1959. (125)
- Humbert H. (1938) Les aspects biologiques du problème des feux de brousse et la protection de la nature dans les zones intertropicales, Bull. Inst. Roy. Col. Belge, 9, No. 3:811. (125)
- Jacques-Felix, H. (1950) Géographie des dénudations et dégradations du sol au Cameroun, Bull. Sci., Section Techn. d'Agricult. Tropicale, No. 3, 126 pp. (144)
- Jurion, F., and J. Henry (1951) Cropping systems in the equatorial forest region of the Belgian Congo, Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources, 6:255-258. (125)

- Lebrun, J. (1943) Les feux de brousses, in: Exploration du Parc National Albert, Fax. 1, 5:69-114. (125)
- LeLeynen (1936) Les feux de brousse, Bull. Inst. Roy. Colon. Belge, 9:804-805. (125)
- Leplae, E. (1938) Les feux de brousse, Bull. Inst. Roy. Colon. Belge, 9:785-790; 806-808. (125)
- Leruth, A. and R. Chambon (1954) Monographie des Bena Muhona, Bull. Agric. Congo Belge, June 1954. (125)
- Letourneux, C. (1957) Le problème des feux au Soudan français, Bois For. Trop., 52:21-28. (142)
- Maher, Colin (1949) Study of the farming systems in their relation to soil conservation: a) mixed farming, b) grass and bush fallows, Bulletin Agric. du Congo belge 40, No. 2:1543-1548 (125)
- Maudoux, E. (1961) Utilization des feux contrôlés pour l'amélioration des groupements naturels et le traitement des jeunes boisements d'essences exotiques en région de forêts claires au Katanga, in: Contribution à l'étude des problèmes du reboisement et de la conservation du sol, préparé par l'INEAC pour la Communauté Économique Européenne, 16 pp. (125)
- Meyer, Hans (1960) The Barundi, HRAF, New Haven, Conn. (127)
- Oubangui-Chari, Service Forestier (1958) Résultats donnés par la protection d'une parcelle de savane contre les feux de brousse dans la région de Bambari, Conférence Interafricaine Forestière, Pointe Noire, 1958. 6 pp. (143)
- Prevost, R. (1957) Etude socio-économique du Plateau Koukuya (1956-1957), French Equatorial Africa, Djambala. (145)
- Quarre, P. (1943) Contribution to study of problem of bush fires for Haut Katanga, E. Afr. Agric. Jour., 9:118-120. (125)
- Risbec, J. (1937) Influence des feux de brousse sur la durée des périodes de sécheresse, Agric. Prat. des Pays Chauds, 12:469. (142)
- Robert, J. L. (1952) Monographie agricole du District du Lac Léopold II, Bull. Agric. Congo Belge, September 1952. (125)
- Robyns, W. (1936) Considérations sur les aspects biologiques du problème des feux de brousse au Congo belge et au Ruanda-Urundi, Bull. Inst. Roy. Col. Belge, 9:383-420 (124, 126, 127)
- Sautter, Gilles (1955) Notes sur l'agriculture des Bakamba de la Vallée du Niari, Bull. Inst. d'Etudes Centrafricaines, No. 9. (145)

- Schumacher, M. A. (1942) Contribution au calendrier agricole indigène du Ruanda, Bull. Agric. Congo Belge, Dec. 1942. (126)
- Sys, C. (1954) Effets des feux de brousse sur la morphologie des sols tropicaux, INEAC, Elisabethville, (mimeo.). (125)
- Thomas, J. M. C. (1960) Sur quelques plantes cultivées chez les Ngbaka de la Lobaye (Republique Centrafricaine), Bull. Inst. d'Etudes Centrafricaines, No. 19-20. (143)
- Tondeur, M. G. (1956) L'agriculture nomade au Congo belge, in: L'agriculture nomade, Vol. 1: Congo belge, Côte-d'Ivoire, pp. 15-108. Rome, F.A.O., also: L'agriculture nomade au Congo belge Bruxelles, 1957, 97 pp. (125)
- Tulippe, O. and J. Wilmet (1964) Géographie de l'agriculture en Afrique Centrale, Bull. de la Soc. Belge d'Etudes Géographiques, 33, No. 2:303-374. (147)
- Tulippe, O. (1955) Les paysannats indigènes au Kasai, Bull. Soc. belge études géogr., 24, No. 1:21-57. (125)
- van Daele, E. (1955) L'agriculture indigène dans la région de Beni-Lubero, Bull. Agric. Congo Belge, December 1955. (125)
- Vanderyst, H. (1920) Contributions a l'étude du palmier à huile au Congo belge: le vin de palme ou malaqu, Bull. Agric. Congo Belge, Sept.-Déc. 1920. (125)
- Vansina, Jan (1954) Les tribus Ba-Kuba et les peuplades apparentées, Annales de Musée Royale du Congo Belge, Série in 8°, Tervuren. (125)
- Wagemans, J. (1961) Influence de la protection des feux sur la reforestation naturelle des savanes guinéennes (expériences du Luki et de Mvuazi), in: Contribution a l'étude des problèmes du reboisement et de la conservation du sol, préparé par l'INEAC pour la Commun. Econ. Europ., 23 p. (122)
- West, O. (1949) L'incendie methodique des pâtures dans les grands élevages de bovides au Congo, Bull. Agric. Congo Belge, 40, No. 2:1941. (125)
- White, C. M. (1959) A preliminary survey of Luvala rural economy, Rhodes-Livingstone Papers, No. 29, Manchester. (125)
- White, C. M. (1948) The material culture of the Lunda-Lovale peoples, Occasional Papers of the Rhodes-Livingstone Museum. No. 3, Livingstone, Northern Rhodesia. (122)

Eastern Africa

- Anderson, R. B., and R. D. Jenner (1954) A summary of eight years of lightning investigation in Southern Rhodesia, Trans. South Africa IEE, Part 7, 45:215-241; Part 9, 45:261-294. (177)
- Blackshaw, G. N. (1920) Ash residues from the burning of peaty soil, Rhod. Agric. Jour., 17:158-160. (176, 177)
- Bogdan, A. (1954) Bush clearing and grazing trial at Kisokon, Kenya, East African Agric. Jour., 19, No. 4:253-259. (172)
- Busse, W. (1907) Deutsch Ost-Afrika, Zentrales Steppengebiet, in: Karsten U. Schenk, Vegetationsbilder, V Reihe, Heft 7, G. Fischer, Jena. (173)
- Cahusac, A. B. (1957) Forest mapping from aerial photographs in Uganda, 7th Brit. Comm. Forestry Confer. 1957. (174)
- Dawkins, H. C. (1954) Timu and the vanishing forests of northeast Karamoja, East Afr. Agric. Jour., 13, No. 3:164-167. (174)
- de Schlippe, Pierre (1954) Le systeme agricole traditionnel des Azandes, Sols Africains, 3:52-63, (parallel translation in English). (166)
- Eyre, V. E. F. et al. (1953) Agriculture, forests and soils of the Jur Ironstone Country of Bahr El Ghazal Province, Sudan, Bull. Minist. Agric. Sudan Govt., 9. (166)
- Fairbairn, W. A. (1945) The central western Sudan and its vegetation, D.Sc. Thesis, Univ. of Edinburgh. (166)
- Fanshawe, D. B. (1960) Burning experiments in Miambo woodland, in: C.S.A. Meeting of specialists on open forests in tropical Africa, Ndola, N. Rhodesia, 1959, Scientif. Council for Africa South of the Sahara, London, Publ. No. 52, 126 pp. (176)
- Fantoli, Amilcare (1960) Contributo pulimenari alba climatologia dell Ethiopia, III, Neghelli, Bongo, Techemiti, Oletta, Dessie, Revista di Meteorologia Aeronautica (Rome), 20, No. 1:3-32. (164)
- Glover, P. E., E. C. Trump and L.E.D. Wateridge (1964) Termitaria and vegetation patterns on the Loita Plains of Kenya, Jour. of Ecol., 52, No. 2:367-378. (172)
- Greenwood, J. E. G. W. (1957) The development of vegetation patterns in Somaliland Protectorate, Geog. Jour., 123, No. 4:465-473. (162)
- Haig, N. S. (1940) Native agriculture: Land tenure in Buganda Province, in: Agriculture in Uganda, J.D. Tothill (ed.), pp. 24-38, London, Oxford University Press. (166)

- Hansford, C. G. (1940) Topography and vegetation, in: J. D. Tothill. ed., Agriculture in Uganda, pp. 7-14. (174)
- Heady, H. F. (1960) Range management in East Africa, Nairobi, Govt. Printer, 126 pp. (170)
- Hursh, C. R. (1960) Composition of the tropical dry forests of Nyasaland, in: C.S.A. Meeting of specialists on open forests in tropical Africa, Ndola, N. Rhodesia, 1959, Scientif. Council for Africa South of the Sahara, London, Publ. No. 52, 126 pp. (176)
- Jewitt, T. N. (1950) Shifting cultivation on the clay plains of the central Sudan, in: Transactions of the Fourth International Congress of Soil Science, 1950, pp. 331-333. (166)
- Kennon, T. C. D., R. R. Staples, and O. West (1955) Veld management in Southern Rhodesia, Rhod. Agricult. Jour., 52:4-21. (177)
- Lewis, E. A. (1953) Land use and tsetse control, East African Agricultural Journal of Kenya, Tanganyika, Uganda and Zanzibar 18, No. 4:160-168. (170)
- Morgan, W. B. (1953) The lower Shire Valley of Nyasaland: a changing system of African agriculture, The Geographical Journal 119:459-469. (178)
- Northern Rhodesia (1946) Annual Report for the year 1945, Northern Rhodesia Dept. of Agriculture, Government Printer, Lusaka, 28 pp. (176)
- Peters, D. H. (1950) Land usage in Serenje District, Rhodes-Livingstone Papers, No. 19, Oxford. (176)
- Phillips, John (1964) Shifting cultivation, in: Proc. and papers of IUCN 9th Tech. Meeting, Nairobi, IUCN pub. new series 4-1964: Part III: The impact of man on the tropical environment, pp. 210-219. (172)
- Richards, Audrey I. (1958) A changing pattern of agriculture in east Africa: the Bemba of Northern Rhodesia, The Geographical Journal, 124:302-314 (176)
- Trapnell, G. G. and Langdale, Brown (1962) The natural vegetation of East Africa, in: Russell, E.W. (ed.), The Natural Resources of East Africa, Nairobi, D. A. Hawkins. Ltd., 144 pp. (172)
- Walter, M. E. (1952) A new presentation of seasonal rainfall of East Africa, East Afr. Agric. Jour., 18:11. (170)
- Wigg, L. T. (1953) Problems of dry forest silviculture in Tanganyika, Emp. For. Rev. 32, No. 3; 212-221. (173)
- Winterbottom, J. M. (1945) The ecology of man and plants in Northern Rhodesia, Rhodes-Livingstone Journal, June 1945. (176)

Southern Africa

- Botha, C. Graham (1924) Notes on early veld burning in the Cape Colony, So. Afr. Jour. Sci., 21:351-352. (191)
- Bowen, B. N. (1964) Studies on Andropogon gayanus, Kunth., III: an outline of its biology, Jour. of Ecol., 52, No. 2:255-272. (190)
- Cook, L. (1939) A contribution to our information on grass burning, So. Afr. Jour. Sci. 36:270-282. (190)
- Crook, A. L. (1950) Some observations on the effects of protection from burning and grazing on secondary succession in the 'Purple Veld' at Frankenwald, with special reference to the regeneration of native trees and shrubs, Thesis, Ecological and Pasture Management Research Station, Frankenwald, University of the Witwatersrand, Johannesburg, South Africa, (mimeo.) n.p. (191)
- Davidson, R. L. and R. E. Altona (1951) Summer rest protects autumn-burnt veld, Farmer's Weekly (S. Africa), Sept. 1957. (191)
- D'Ions, J. (1960) Studies in veld burning, M.Sc. Thesis, Univ. Natal, n.p. (mimeogr.) (191)
- Dommergues, J. (1952) Influence du défrichement de forêt suivi d'incendie sur l'activité biologique du sol, Mémoires Inst. Sci. Madagascar, Sér. D., tome IV, fasc. 2, pp. 273-296. (180)
- Edwards, P. J. (1961) Studies of veld burning and mowing in the tall grass veld of Natal, Univ. of Natal, Natal, n.p. (mimeogr.) (191)
- Edwards, P. J. (1965) The effect of twenty years of burning and mowing on the basal cover (point method) of two veld types in South Africa, International Grassland Congress, Brazil. (191)
- Fenies, J. (1958) L'arbre et le feu, B. de Madagascar, 8, No. 141:89-90. (180)
- Gill, G. A. (1936) Veld-burning experiments, Farming in So. Africa, 2:134. (191)
- Jansen, P. J. (1959) The influence of burning on grasses and soil structure of Trachypogon -- other species veld, at Frankenwald, Transvaal, Ecological and Pasture Management Research Station, Frankenwald, University of the Witwatersrand, Johannesburg, South Africa, n.p. (mimeo). (191)
- Kiener, A. (1963) The 'Tavey' in Madagascar, the different methods and names: the balance of the tavey and human problems. means of control (in Fr.), Bois et Forêts des Trop., 90:9-16. (180)

- Levy's, M. R. (1929) Veld burning experiments at Ida's Valley, Stellenbosch, Trans. Roy. Soc. So. Africa, 17, No. 2:61-92. (190)
- Levy's, M. R. (1935) Veld burning experiments at Oakdale, Riversdale, Trans. Roy. Soc. So. Africa, 23:231. (190)
- Lowe's, J. (1964) M. Sc. Thesis on veld burning, Univ. Witwatersrand, Johannesburg, (mimeogr.) (191)
- Marloth, R. (1924) Notes on the question of veld burning, So. Afr. Jour. Sci., 21:342. (191)
- Michell, M. R. (1921) Some observations on the effects of a bush fire on the vegetation of Signal Hill, Trans. Roy. Soc. So. Africa, 10:213. (191)
- Nanni, U. W. (1960) The immediate effects of veld-burning on streamflow in Cathedral Peak catchments, Jour. So. African For. Assoc., 34:7-12. (190)
- Phillips, E. P. (1920) A preliminary report on the veld burning experiments at Groenkloof, Pretoria, So. African Jour. Sci., 16:285-299. (191)
- Phillips, E. P. (1921) Veld burning experiments at Groenkloof, Second Rept. Sci. Bull. 17, Union of South Africa. (191)
- Pillans, N. S. (1924) Destruction of indigenous vegetation by burning in the Cape Peninsula, So. African Jour. Sci., 21:348-350. (191)
- Scholz, E. (1941) A report on the veld burning experiments at Crescent Creek, Milner Park, Johannesburg, Univ. Witwatersrand, Johannesburg, (mimeogr.) (191)
- Smit, I. B. (1954) Seasonal burn experiment in Trachypogon - other species grassland at Frankenwald, Univ. Witwatersrand, Johannesburg, (mimeogr.) (191)
- Smit, I. B. (1954) The effect of veld burning on Stoebe vulgaris, Univ. Witwatersrand, Johannesburg, (mimeogr.) (191)
- Southern Rhodesia Dept. of Agricult., Division of Forestry (1938) The control of veld fires, Rhod. Agr. Jour., 35: 243-246. (177)
- Staples, R. R. (1945) Veld burning, Rhodesia Agric. Jour., 42:44-52. (190)
- Thompson, W. R. (1936) Veld burning: its history and importance in South Africa, Bull. Univ. Pretoria, Ser. 1, No. 31:1-31. (190)
- Vignal, P. (1958) Prévision des incendies de forêt sur les hauts plateaux de Madagascar, Conférence Interafricaine Forestière, Pointe Noire, 1958, 4 pp. (180)

Viljoen, A. (1961) Brandbestryding en die bewaring van bergopvangeebiede in die Winterreemstreek, Farming in So. Africa. (190)

West, O. (1958) Bush encroachment, veld burning and grazing management, Rhodesia Agric. Jour., 55, No. 4:407-425. (190)

West, O. (1964) Fire in vegetation and its use in pasture management, with special reference to tropical and subtropical Africa, MS: in press, Commwlth. Agr. Bureaux. (190)

West, O. (1949) Les feux de brousse a Madagascar, Bull. Agric. Congo Belge, 40, No. 2:1945. (180)

Latin America General

Aristeguieta, L. (1959) Plantas indicadoras de incendios anuales, Bol. Soc. Venezol. de Cien Nat., 20, No. 94:337-47. (200)

Budowski, Gerardo (1959) The ecological status of fire in tropical American lowlands, Boletin del Museo de Ciencias Naturales 4-5, No. 1-4:113-127. (200)

Holdridge, Leslie Rensselaer (1959) Ecological indications of the need for a new approach to tropical land use, Symposia Interamericana, No. 1:1-12, 58, Comments by Bates (p. 13), Camargo (pp. 14-25), Marrull (p. 26), Morrison (pp. 27-36), Ochse (pp. 37-38), Robb (pp. 40-48), Skutch (pp. 49-57). Costa Rica, Turrialba. (200)

Johnson, Frederick (1948) The Caribbean lowland tribes: the Talamanca division. in: Steward, J.H., ed., Handbook of South American Indians, Smithsonian Instit., Bureau of American Ethnology Bull. 143, pp. 231-251. (200)

Kirchhoff, Paul (1948) The Caribbean lowland tribes: the Mosquito, Sumo, Paya, and Jicaque. in: Steward, J. H., ed., Handbook of South American Indians, Smithsonian Instit., Bureau of American Ethnology Bull., 143, pp. 219-229. (200)

Meggers, Betty J. (1959) Comments (on The ecology of tropical farming systems, by James M. Blaut), Plantation systems of the New World, Pan American Union, Social Science Monographs, 7, pp. 98-99. (200)

Suarez de Castro, F. (1956) La quema como práctica agrícola y sus efectos, Tesis Mag. Agr., IICA, Turrialba, Costa Rica, 53 pp. (mimeogr.) (200)

Middle America

Altschuler, Milton (1958) On the environmental limitations of Mayan cultural development, Southwestern Jour. of Anthropol. 14:189-198. (221)

- Aschmann, Homer (1960) The subsistence problem in mesoamerican history, Middle American anthropol., Soc. Sci. Monogr. 10, Vol. 2:1-8, Pan Amer. Union. Wash. (220)
- Bevan, Bernard (1938) The Chinantec-report on the central and Southeast Chinantec region, Vol. I, The Chinantec and their habitat, Pan Amer. Inst. of Geogr. and Hist. Publ. No. 24. (221)
- Borhegyi, Stephan F. de (1956) Settlement patterns in the Guatemalan highlands: past and present, Prehistoric settlement patterns in the new World, Willey, G. R. ed., Viking Fund Publ. in Anthropol., New York, No. 23, pp. 101-106. (222)
- British Honduras (1946) Causes and prevention of fire on the Mountain Pine Ridge, Report For. Dept. Report 1945. n.p. (228)
- Bullard, William R., Jr. (1960) Maya settlement pattern in northeastern Peten, Guatemala, American Antiquity 25, No. 3:355-372. (222)
- Campbell, R. S. (1955) Las quemadas en relacion con el pastoreo de los montes, Mensajero Forestal (Mexico), 134: 16-26. (221)
- Chanto, M. (1931) Los arboles, las fuentes y las quemadas, Escuela de Agricultura. Costa Rica, Tomo III (X):233-255. (226)
- Dozier, C. L. (1958) Indigenous tropical agriculture in Central America: land use, systems and problems, Nat. Acad. of Sci., Nat. Res. Coun., Wash., 134 pp. (220)
- Dumond, D. E. (1961) Swidden agriculture and the rise of Maya civilization, Southwestern Jour. of Anthropol. 17, No. 4:301-316. (220)
- Hermesdorf, R. I. (1960) Los incendios forestales y las informaciones de prensa, Mex. Agric. 7, No. 73:42. (221)
- Holdridge, L. R., B. F. Lamb, and B. Mason (1950) Los bosques de Guatemala, Instituto Interamericano de Ciencias Agricolas e Instituto de Fomento de la Produccion de Guatemala, Turrialba, Costa Rica, 174 pp. (222)
- Holdridge, Leslie R. and G. Budowski (1957) Report of an Ecological Survey of the Republic of Panama, Caribbean 17:92-110. (227)
- Huizar, M. G. (1954) Los "inocentes" incendios forestales destruyen la materia organica, Tierra [Mexico], 9:388. (221)
- Hunt, D. R. (1962) Some notes on the pines of British Honduras, Emp. For. Rev., 41, No. 2:134-145. (228)

- Lauer, Wilhelm (1959) Klimatische und pflanzengeographische Grundzüge Zentralamerikas, Erdkunde, Bonn 13, No. 4:344-354. (220)
- Lauer, Wilhelm (1954) Las formas de la vegetacion de El Salvador, Instituto Tropical de Investigaciones Cientificas, Comunicaciones 3:41-45. (223)
- Lötschert, Wilhelm (1959) Vegetation und Standortsschema in El Salvador: eine pflanzengeographisch-ökologische Studie Botanische Studien, Heft 10:88 pp. (223)
- McBryde, Felix Webster (1947) Cultural and historical geography of Southwest Guatemala, Inst. of Soc. Anthropol. Publication No. 4, Smithsonian Institution, 184 pp. (222)
- Perry, J. P., Jr., G. Gil, Raul Franco, and Jorge Martinez Lima (1958) Efecto de la quema del monte sobre las propiedades quimicas de un suelo en Campeche, Escuela Nacional de Agricultura, Chapingo, Mexico. (221)
- Taylor, B. W. (1959 & 1961) Ecological Land Use Surveys in Nicaragua, Vol. I - 1959, Vol. II - 1961, Instituto de Fomento Nacional, Managua. (225)
- Taylor, B. W. (1963) Estudios ecologicos para el aprovechamiento de la tierra en Nicaragua, Vol. I, FAO, Instituto de Fomento Nacional, Nicaragua, 338 pp. (225)
- Taylor, B. W. (1962) The status and development of the Nicaraguan Pine Savannas, Caribbean For., 23, No. 1:21-26. Rio Piedras, Puerto Rico. (225)
- Valenzuela, J. L. et al. (1957) El problema de las quemas en Costa Rica, Ministerio de Agric. e Industrias, Boletín misceláneo No. 2, 22 p, San Jose, Costa Rica. (226)
- Williams, Louis O. (1957) The subsistence agriculture of Lake Yojoa, Honduras, Economic Bot. 11, No. 3:249-256. (224)

Insular Caribbean and Bahamas

- Cater, J. C. (1939) Deforestation and soil erosion in Trinidad, Trop. Agric., Trinidad, 16:293-295. (235)
- De Young, Maurice (1958) Man and land in the Haitian economy, Latin American Monographs No. 3, 73 pp., University of Florida. (231)
- Holly, M. A. (1955) Agriculture in Haiti, with special reference to rural economy and agricultural education, New York, Vantage Press, 313 pp. (231)
- Murray, C. H. (1961) Peak and fire in Trinidad, Carib. For., 22, No. 3-4:57-61. (235)

South America

- Alvim, P. de T. (1952) Soils as an ecological factor in development of vegetation in the Central Plateau of Brasil, Sixth International Grassland Conference, Penn. State College, U.S.A., 1952, Vol. 1: pp. 610-616. also: El suelo como factor ecologico en el desarrollo de la vegetacion en el centro oeste del Brasil, Turrialba 2(4): 153-160, 1952. (241)
- Alvim, P. de T., & Araujo, W. A. (1954) Teoria sobre a formação dos campos cerrados, Vultos da Geografia do Brasil, pp. 486-498. (241)
- Anonymous (1957) Fuegos forestales en Venezuela, El Agricultor Venezolano, 21, No. 193:4-23. (255)
- Anonymous (1955) El problema de los incendios en Venezuela, Agric. Venez 20, No. 182:18-23, 26: 20, No. 183:16-19, 52. (255)
- Anonymous (1952) Quemas e incendios forestales, El Agricultor Venezolano, 17, No. 158:39-43. (255)
- Aubréville, A. (1962) Étude écologique des principales formations végétales du Brésil, Jauve, Paris, 268 pp. (241)
- Aubréville, A. (1948) Quelques problèmes forestier du Brésil; la forêt de Pin de Parana les plantations d'Eucalyptus, Bois et Forêts des Tropiques, 6, No. 2:102-117. (241)
- Barros, D. P. De (1956) Observações sobre sistemas de preparo do solo em silvicultura, Rev. Agric. Piracicaba, 31, No. 2:79-82. (241)
- Bennett, H. H. et al (1942) Land conditions in Venezuela and their relations to agriculture and human welfare, U.S. Soil Conservation Service, Wash., D.C. (255)
- Blydenstein, J. (1962) La sabana de Trochypogon del Alto Llano, Boletín Sociedad Venezolana de Ciencias Naturales, 23, No. 102:139-206. (255)
- Blydenstein, J. (1963) La vegetación en el estero del Río Guariquito, Boletín Sociedad Venezolana de Ciencias Naturales, 23, No. 103:229-246. (255)
- Briceño, V. A. (1948) Riqueza forestal del Estado Trujillo, El Agricultor Venezolano, 13, No. 132:8-9. (255)
- Carneiro, Robert (1957) La cultura de los indios Kuikurus del Brasil Central, I: La economia de subsistencia, Runa 3 (Part 2):169-185. (241)
- Carneiro, Robert (1957) Subsistence and social structure: an ecological study of the Kuikuru Indians, 339 pp., Unpubl. Ph.D. Thesis, University of Michigan. (241)

- Carneiro, Robert (1961) Slash-and-burn cultivation among the Kuikuru and its implications for cultural development in the Amazon Basin, in: The evolution of horticultural systems in native South America: causes and consequences Johannes Wilbert, ed., Anthropologica Supplement Publication No. 2:47-68, Sociedad de Ciencias Naturales La Salle, Caracas. (241)
- Cole, N. N. (1960) Cerrado, caatinga and pantanal; the distribution and origin of the savanna vegetation of Brasil, Geog. Jour., 126, No. 2:163-179. (241)
- Cristoffel, H. M. (1939) Exploracion de la Gran Sabana, Revista de Fomento (Venezuela), 19:501-726. (255)
- Davis, T. A. W. (1929) Some observations on the forest of the North West District, Agric. Jour. of British Guiana 2:157-166. (251)
- Ellemberg, H. (1961) Asociacion de plantas y sus condiciones biologicas en el Peru, Agronomia, 28, No. 1-2:7-18. (261)
- Ellenberg, H. (1958) Wald oder Steppe? Die natürliche Pflanzendecke der Anden Perus, Die Umschau, 645-648 and 679-681. (261)
- Ferri, M. G. (1955) Contribucao ao conhecimento da ecologia do curado e da castinga. Estudo comparativo da economia d'agua de sua vegetacao, Bol. Fac. Fil. Cienc. Letr. Vol. 195, Botanica No. 12:1-170. (240)
- Frei, E. (1958) Eine Studie über den Zusammenhang zwischen Bodentyp, Klima und Vegetation in Ecuador, Plant & Soil 9, No. 3:215-236. (260)
- Freise, F. W. (1936) Das Binnenklima von Urwäldern in subtropischen Brasilien, Petermanns Mitteilungen, 82:281-289. (241)
- Freise, F. W. (1939) As queimadas e suas influências nefastas sobre os solos tropicais, Bol. Agric. [São Paulo] No. 1: 631-659. (241)
- Gillin, John (1948) Tribes of the Guianas and the left Amazon tributaries. in: Handbook of South American Indians Bureau of American Ethnology Bulletin 143, 3:799-860, Smithsonian Institution, Wash. (251, 255)
- Gonggryp, J. W. and Burger (1948) Bosbouwkundige studien over Suriname, Publicatie No. 32 "Fonds Landbouw Export Bureau 1916-1928", Wenman & Zonen, Wageningen (Holand), 262 pp. (252)
- Hueck, K. (1957) Die Ursprünglichkeit der brasilianischen 'campos cerrados' und neue Beobachtungen an ihren Südgrenzen Erdkunde 11, No. 3:193-203. (241)

- Jones, T. A. et al (1958) British Guiana, the Rapunini savannas. Soil and Land use Survey No. 2, Imperial College of Agriculture, Trinidad, B.W.I., 33 pp. (252)
- Kuhimann, E. (1952) Vegetacao campestre do Planalto Meridional do Brasil, Revista Bras. de Geogr., Ano 14, No. 2, pp 181-198 (241)
- Lasser T (1955) Esbozo preliminar sobre el origen de las formaciones vegetales de nuestros llanos, Boletín de la Sociedad Venezolana de Ciencias Naturales, 16, No. 84:173-200 (255)
- Lima R. R (1959) The effects of burning vegetation on sandy soils of the Braganca railroad region [In Portuguese] Brazil Div. de Fomento de Prod. Veg. Insp. Region de Fomento Agr. no Estado do Pará B. 8, No. 1:23-36. (241)
- Maack, R (1962) New researches in Paraguay and on the Paraná River; the flood plains of the Monday and Acaray [in German] Erde 93. No 1:4-48. (263)
- Maack, R (1948) Preliminares sobre a vegetação de Estado do Paraná. Arquivos Biol. e Tecnol., 3:103-200. (241)
- Rawitscher, F. K. (1942) Problemas de fitoecología con consideração especiais sobre o Brasil Meridional, Univ. São Paulo Bol. No 28, Brasil. (241)
- Rawitscher, F., M. G. Ferri and M. Rachid (1943) Profundidade dos solos e vegetacao em campos cerrados do Brasil Meridional, Anais da Acad. Bras. Cienc. (Rio de Janeiro), 15, No 4:267-294. (241)
- Schmidt, R. D. (1952) The distribution of rains in the Colombian Andes [in German], Bonner Geogr.-Abhandlungen, Heft 9. (250)
- Schroeder, R (1952) The distribution of mean temperatures in Colombia. [in German], Bonner Geogr.-Abhandlungen, Heft 9. (250)
- Steward, Julian H (ed.) (1946-50) Handbook of South American Indians. Vols. 1-6, Smithsonian Institution, Bureau of American Ethnology Bulletin 143, 4787 pp. Washington. (240)
- Suarez de Castro, and R. Rodriguez (1955) Perdidas por erosion de elementos nutritivos, bajo diferentes cubiertas vegetales y con varias practicas de conservacion de suelos, Federacion Nac. de Cafeteros de Colombia, Boletin Tecnico No. 14, Chinchina, Caldas, Colombia. (250)
- Suarez de Castro, F. (1963) La quema como práctica agricola y sus efectos. Conferencia dictada en la Universidad Central de Venezuela, 15 de mayo 1962, Fundación Shell, Caracas, Venezuela, pp. 18-30. (255)

- Swellengrebel, E. J. G. On the value of large scale aerial photographs in British Guiana Forestry, Empire For. Rev. 38:54-64. (251)
- Tamayo, F. (1963) The xerophyllous woods of Maracaibo [in Spanish], Soc. Venezol. de Cien. Nat. Bull. 23, No. 103: 294-299. (255)
- Tortorelli, L. A. (1964) Efecto del fuego en los bosques del Estado Parana, Brasil, Bol. del Inst. Latino Americano (Venezuela), 14:93-96. Also: Montes (España), 20, No. 117: 261-262 (241)
- Vareschi, V. (1960) Efectos del viento en los llanos, durante la época de sequia, Soc. Venezol. de Cien. Nat. B. 21, No. 96:118-127. (255)
- Veillon, J. P. (1963) Relacion de ciertas características de la masa forestal de unos bosques de las zonas bajas de Venezuela con el factor climatico: Acta Cientifica Venezolana 2, No. 14:30-41. (255)
- Waibel, L. (1955) Die europäische kolonisation Südbasiliens, Colloquium Geographicum, Band 4, Bonn, 152 pp. (241)
- Whitton, B. A. (1962) Forest and dominant legumes of the Amatuk regions, British Guiana, Carib. For., 23, No. 1: 35-57. (252)
- Williams, R. L. (1958) Informe al gobierno de Venezuela sobre la prevencion y extincion de incendios, FAO Report No. 847. 22 pp. (255)

Asia

- Burns, W., L. B. Kulkarni & S. R. Godbole (1933) Grassland problems in Western India, Dept Agric. Bull. 171, Bombay. n.p. (340)
- Chapman, H. H. (1927) Use of fire in regeneration of certain types of forests in India, Jour. Forestry 25(1):92-94. (340)
- Coorey, P. G. (1948) Effective rainfall and moisture zones in Ceylon, Bull. of the Ceylon Geogr. Soc. 3:39-42. (336)
- Farmer, B. H. (1952) Colonization in the Dry Zone of Ceylon, Jour. Royal Soc. 100:547-564. (336)
- Farmer, B. H. (1953) Problems of land use in the dry zone of Ceylon, Geogr. Jour., 120:21-33 (336)
- Farmer, B. H. (1957) Pioneer peasant colonization in Ceylon: a study in Asian agrarian problems, Oxford University Press, London, 378 pp. (336)
- Fürer-Haimendorf, Christoph von (1946) Agriculture and land tenure among the Apa Tanis, Man in India 26:20-49. Ranchi. (340)

- Fürer-Haimendorf, Christoph von, and Elizabeth (1943) The aboriginal tribes of Hyderabad, Vol. 2: The Reddis of the Bison Hills, Macmillan and Co., London, 364 pp. (340)
- Gourou, Pierre (1949) The development of upland areas in China, in: The development of upland areas in the Far East, Vol. 1, pp. 1-24, Inst. of Rel. Pacif. New York. (300)
- Griffith, A. L. (1947) The effects of artificial soil regeneration by burning in India, Ind. For., 12:526-528. (300)
- Holmes, C. H. (1948) Climate and vegetation with special reference to Ceylon, Ceylon Geog. Soc. Bull. 3(2): 32-38. (336)
- Holmes, C. H. (1951) The climate and vegetation of the dry zone of Ceylon, Ceylon Geogr. Soc. Bull. 5(4), and 6(1): 145-152. (336)
- Jamwal, H. S. (1939) Effect of slash burning on soil and succeeding vegetation, Ind. For. 65:39-42. (340)
- Kandiah, S. (1948) The effect of shifting (chena) cultivation and subsequent regeneration of vegetation on soil composition and structure, Trop. Agriculturist 104:3-11. (330)
- Laurie, M. V. (1939) Effect of slash burning on soil and succeeding vegetation, Ind. For. 65:43-44. (340)
- Merritt, V. G. and M. S. Ranatunga (1959) Aerial photographic survey of the Sinharaja Forest, Ceylon For. (New series) 4(2):103-156. (336)
- Munokur, S. A. (1960) Forest fire damage in deciduous forest, Silviculture (fr. [India] Proc. 9(2):395-397. (340)
- Pandeya, S. C. (1961) Ecology of grasslands of Sagar, Madhya Pradesh. Part I Grassland map of the area on physiographic basis. Indian Bot. Soc. Jour. 40(4): 592-600. (340)
- Rasmussen, Tor. Fr. (1960) Population and land utilization in the Assam valley, Jour. of Trop. Geogr. 14:51-76. (340)
- Rosayro, R. A. de (1947) A new viewpoint on the origin of montane grasslands of Ceylon, British Emp. For. Conf. 1947, Colombo, Ceylon Govt. Press., n.p. (336)
- Tamasis, Florencio (1960) Problems of shifting agriculture in the Asian area, Proc. Fifth World Forestry Congress, Seattle 1960, Vol. 3:2015-2031. (300)
- Thomas, H. R. (1938) Effect of burning of slash on soil and succeeding vegetation, Ind. For. 64:362-364. (340)
- Udugama, P. P. (1947) Some observations on shifting cultivation in Ceylon, Bull. Ceylon Geogr. Soc. 2:30-35. (336)

Wijayapala, W. A. L. (1958) Certain aspects of settlement and topography in the Rakwana region of Ceylon, Bull. Ceylon Geogr. Soc. 10(3 & 4):67-77. (336)

Wikkramatilleke, Rudolph (1957) Whither 'chena'? The problem of an alternative to shifting cultivation in the dry-zone of Ceylon, Geogr. Studies 4:81-89. (336)

Southeast Asia

Ablibut, A. P. et al (1951) The influence of rainfall and cultural practices on soil erosion and surface run off, Philippine Agric., Vol. 30. (366)

Anthony, K. R. M. and F. R. Moormann (1965) Agricultural problems and potentialities of a hill tribe area in Thailand, Trop. Agriculture 42:97-104. (352)

Brillet, F. (1929) Le "Ray" au Tonkin, Annales Forestières Indo 1929, No. 3, p. 28-34. (350)

Cenabre, Agapito L. (1954) Shifting cultivation in the Philippines, 244 pp., FAO, Rome. (366)

Champsoloix, R. (1960) Le ray dans quelques villages des hauts plateaux du Viet Nam dans Rapports du sol et de la végétation, Paris, Masson. (355)

Cole, Fay-Cooper (1922) The tinguian, social, religious, and economic life of a philippine tribe, Field Museum of Natural history Publication 209. Anthropological Series 14.2:229-493. (366)

Cole, Fay-Cooper (1956) The Bukidnon of Mindanao, Fieldiana: Anthropology, Vol. 46, 146 pp. (366)

De Rosayro, R. A. (1949) "Some Aspects of Shifting Cultivation in Ceylon", Tropical Agriculturist, 105. (336)

Dobby, E. H. G. (1951) The development of Malaya's uplands, in: The development of upland areas in the Far East, Vol. 2:1-21, Inst. Pacif. Rel. New York. (350)

Freeman, J. D. (1955) Iban agriculture, a report on the shifting cultivation of hill rice by the Iban of Sarawak, Colonial Research Studies, Vol. 18, 148 pp., London: HMSO (362)

Fukuhara, Tomokichi (1943) Hirippin no nogyo [The agriculture of the Philippines], (in English), 2 Vols., 309 and 463 pp., Tokyo, Osaka:Sanseido. (366)

Gourou, Pierre (1951) "Land utilization in upland areas of Indochina," in: The development of upland areas in the Far East, Vol. 2, pp. 25-42, New York, Inst. Pacif. (353)

Hamada, Hideo (1959) Lao and Miao farming on the plateau Xieng-Khouang, Laos, Minzokugaku-Kenkyu 23.1-2:25-43 summary in English. Tokyo. (354)

- Jocano, Felipe Landa (1958) The Sulod: a mountain people in Panay Island Philippines, Philippine Studies 6.4:401-436, Manila. (366)
- Kauffmann, Hans-Eberhard (1935) Landwirtschaft der den Bergvölkern von Assam und Nord-Burma, Zeitschrift für Ethnologie 66:15-111, Berlin. (351)
- Keith, H. G. (1953) Recommendations concerning the abolition of shifting cultivation in Southeast Asia, in: Eighth Pacific Science Congress of the Pacific Science Association, Abstract of papers, pp. 349-350. Manila (350)
- Lafont, Pierre-Bernard (1957) The 'slash-and-burn' (ray) Agricultural system of the mountain populations of Central Vietnam, Ninth Pacific Science Congress Abstracts of Papers, p. 79. Organizing Comm., Bangkok, Thailand. (356)
- Loetsch, F. (1958) Der Einfluss des Brandrodungsbaus auf das Gefüge des Tropenwaldes und die Wasserführung der Ströme... Nordthailands, Erdkunde 12:182-205, Leipzig. (352)
- Miller, R. W. R. (1954) The uplands of South-East Asia, Sarawak Museum Journal 4.4: (new series):96-103, Kuching. (362)
- Spencer, J. E. (1952) Land and peoples in the Philippines, Geographical Problems in Rural Economy, 282 pp., University of Calif. Press, Berkeley. (366)
- Spencer, J. E. (1949) "Land use in the upland Philippines," in: The development of upland areas in the Far East, Vol. 1:26-57, Inst. Pacif. Rel., New York. (366)
- Spurway, B. J. C. (1937) Shifting cultivation in Sarawak, Sarawak Gazette 57.1003:81-82, Kuching. (362)
- Thomas, William L., Jr. (1957) Land, man, and culture in mainland Southeast Asia, 197 pp., Glen Rock, New Jersey: [privately published by the author.] (350)
- Watts, I. E. (1955) Equatorial weather, with particular reference to Southeast Asia, London, Univer. of London Press, 1955, 224 pp. (350)

Indonesia

- Barrau, J. (1959) Esquisse écologique de la Nouvelle-Guinée. Terre et Vie 106(4):291-306, (378)
- Barrie, J. W. (1956) Population-land investigation in the Chimbu sub-district, The Papua and New Guinea Agricultural Journal 11.2:45-51. Port Moresby. (378)
- Brookfield, H. C. (1961) The highland peoples of New Guinea: a study of distribution and localization, Geographical Jour., Vol. 127:436-448. (378)

- Brown, Paula and H. C. Brookfield (1959) Chimbu land and society, Oceania 30 1:1-75, Sydney. (378)
- Burger, D. (1936) Bliksem als oorzaak van bosbrand, Tectona. (370)
- Burger, D. (1930) Brand in gebergtebos, Tectona. (370)
- Conroy, W. L. and L. A. Bridgland (1947) Native Agriculture in Papua, New Guinea. Report of the New Guinea Nutrition Survey Expedition. Canberra, pp. 75-92. (378)
- DeHaan, J. H. (1950) Shifting cultivation in Indonesia, Trans. Fourth Internat. Congress of Soil Science, 1950, pp. 314-320, Amsterdam. (371)
- De Jong, B. (1923) Bosbrandbestrijding in het bosdistrict Pekalongan-Kendal (Java) in 1922, Tectona. (373)
- Howlett, D. R. (1962) A decade of change in the Goroka Valley New Guinea; land use and development in the 1950's, Ph.D. Thesis in Geography, Australian National University. (378)
- Jaski, K. C. (1912) Het branden op te cultiveerenterrainen, Tectona. (370)
- Landtman, Gunnar (1927) The Kiwai Papuans of British New Guinea, 485 pp, Macmillan and Co., London. (378)
- Marr, C. C. (1938) An agricultural survey of the Markham Valley in the Morobe District, New Guinea Agricultural Gazette 4.1:2-12, Rabaul. (378)
- Meggitt, M. J. (1958) The Enga of the New Guinea Highlands: some preliminary observations, Oceania 28:253-330. (378)
- Ormeling (1957) The Timor problem: a geographical interpretation of an underdeveloped island, Martinus Nijhoff, Gravenhage, 284 pp. (374)
- Paijmans, K. (1951) Interpretation of aerial photographs in virgin forest complex, Malili Celebes, Tectona. (376)
- Richards, P. (1936) Ecological observations on the rain forest of Mount Dulit, Sarawak, Jour. of Ecol. 24.1-37; 340-360 (375)
- Schindler, A. J. (1952) Land use by natives of Aiyura Village Central Highlands New Guinea, South Pacific 6:302-307. (378)
- Specht, R. L. (1958) The climate, geology, soils and plant ecology of the Northern Portion of Arnhem Land, Amer. Austr. Sci. Exp. to Arnhem Land 3:333-413. Melb. Uni. Press. (378)
- Tergar, G. C. W. Chr., and E. de Vries. (1951) Utilization of pland areas in Indonesia and western New Guinea, in: The development of upland areas in the Far East, Vol 2: 45-100, Inst. of Pacif. Rel., New York. (371)

- Thompson, D. F. (1949) Arnhem Land - explorations among an unknown people Part II, Geogr. Jour. 113:1-8. (378)
- Timmer, P. (1911) Bosbrandbescherming in de houtvesterij N. Kradenan, Tectona. (370)
- Van Eck, C. R. S. Ritsema (1920) Nota betreffende de bescherming der in stand te houden wildhoutbossen in het gebergte tegen bosbranden, Tectona. (370)
- Vicary, J. R. (1960) The agricultural year at Yabob village, Papua-New Guinea Agricultural Journal, 12.4:180-191, Port Moresby. (378)
- Vicedom, Georg F., and Herbert Tischner (1943-48) Die Mbowamb: die Kultur der Hagenberg-Stämme im östlichen Zentral-Neuguinea, Hamburgischen Museum für Völkerkunde, Monographien zur Völkerkunde, No. 1, Vol. 1, Cram, de Gruyter and Co., Hamburg, 264 pp. (378)
- Vroklage, B. A. G. (1953) Ethnographie der Belu in Zentral-Timor, 3 Vols., E. J. Brill, Leiden. (377)
- Wyatt-Smith, J. (1953) A note on the vegetation of some islands in the Malacca Straits, Malay Forester 16:191-205. (370)

Australia and Oceania

- Anonymous (1959) Brush fires in Australia [in French], Prct. Civile, 63:37-8. (450)
- Australia (1947) A study of meteorological conditions associated with bush and grass fires and fire protection strategy, Bureau of Meteor. of Australia, Bull. 38: (450)
- Barid, A. M. (1958) Notes on the regeneration of vegetation of Garden Island after 1956 fire, Royal Soc. West Aust. Jour. 41(4):102-107 (450)
- Barrau, Jacques (1956) L'agriculture vivrière autochtone de la Nouvelle-Calédonie, Document Technique No. 87, 153 pp., Commission du Pacifique Sud. Noumea. Also: Journal de la Société des Oceanistes (1956) 12:181-216. Paris. (400)
- Barrau, Jacques (1956) Polynesian and Micronesian subsistence agriculture, South Pacific Commission, Noumea, 139 pp. (430/440)
- Barrau, Jacques (1954) Traditional subsistence economy and agricultural progress in Melanesia, South Pacif. Comm. Quart. Bull. 4.3:2-7, Noumea. (420)
- Barrau, Jacques (1961) Subsistence agriculture in Polynesia and Micronesia, Bernice P. Bishop Museum Bull. 223, Honolulu, 94 pp. (430/420)

- Bauer, F. H. (1964) Historical geography of white settlement in part of Northern Australia, Part 2, The Katherine-Darwin Region, C.S.I.R.O. Div. Land Res. Report 64/1. (450)
- Burbridge, Nancy T. (1943) Ecological succession observed during regeneration of Triodia pungens R. Br. after burning, Jour. Roy. Soc. Austr. 28:149-156. (450)
- Firth, Raymond (1939) Primitive Polynesian economy, George Routledge and Sons, London, 387 pp. (440)
- Fox, J. W. and K. B. Cumberland (1963) Western Samoa: Life and agriculture in tropical Polynesia, Whitcomb & Tombs, Christchurch, New Zealand, 337 pp. (440)
- Gardner, C. A. (1957) The fire factor in relation to the vegetation of Western Australia, Western Australian Naturalist 5:166-173. (450)
- Gentilli, J. (1948) Bioclimatic controls in Western Australia, Western Australian Naturalist Vol. I, No. 6. (450)
- Hatch, A. B. (1960) Ash bed effect on Western Australia forest soils, West Austral. Forest. Dept. Bull. 64:20 pp. (450)
- King, A. R. (1964) Characteristics of a fire induced tornado Austral. Meteorological Mag. 44. (450)
- King, A. R. and M. Linton (1963) Moisture variation in forest fuels; the rate of response to climate changes, Aust. Jour. Appl. Sci. 14(1):38-49. (450)
- McArthur, A. G. (1958) The preparation and use of fire danger tables, Proceedings, Fire Weather Conference, Melbourne, Conference paper No. 10, 1958. (450)
- Mercer, J. H. and Peter Scott (1958) Changing village agriculture in western Samoa, Geogr. Jour. 124:347-360. (400)
- Mount, A. P. (1964) The interdependence of the eucalypts and forest fires in southern Australia, Austral. Forestry 28, No. 3. (450)
- Norman, M. J. T. and R. Wetselaar (1960) Losses of nitrogen on burning native pasture at Katherine Northern Territory Australia, Inst. Agri. Sci. Jour. 26(3):272-273. (450)
- Norman, M. J. T. (1963) The short term effects of time and frequency of burning on native pastures at Katherine, Northern Territory Aust. Jour. of Exp. Agric. & Anim. Husb. 3:26-29. (450)
- Perry, R. A. (1960) Pasture lands of the Northern Territory, Australia, C.S.I.R.O. Aust. Land Res. Ser. No. 5. (450)
- Robbins, R. G. (1963) The Anthropogenic Grasslands of Papua and New Guinea, Proc. UNESCO Symposium on The Impact of Man on the Vegetation of the Humid Tropics, Goroka, pp. 113-29.

- Robbins, R. G. (1961) "Vegetation", Chapter 6, in: C.S.I.R.O. Report, Lands of the Wewak-Lower Sepik Area, Division of Land Research and Regional Survey, No. 61/2, Canberra. (378)
- Sachet, M. H. (1957) The vegetation of Melanesia: a summary of the literature, Proc. Eighth Pacific Sci. Cong. 1953 8(4):35-47. (420)
- Sarlin, P. (1950) Les feux de Brousse, Rev. Agr. de la Nouvelle-Caladonie (new series) 1(11/12).7-8. (420)
- Smith, E. L. (1960) Effects of burning and clipping at various times during the wet season on tropical tall grass range in Northern Australia, Jour. Range Management, Comm. of Austr., C.S.I.R.O. 13:197-203. (450)
- Speck, N. H. (1963) Vegetation of the North Kimerley area, West Australia, C.S.I.R.O. Land Res. Sur. 4:41-63. (450)
- Watters, R. F. (1958) Cultivation in old Samoa, Econ. Geogr. 34.4:338-351. (400)
- Wood, J. G. (1959) The phytogeography of Australia, Monog Biol. 8:291-302. (450)
- Wood, J. G. and R. J. Williams (1960) Vegetation, in: C.S. I.R.O., The Australian environment, (3 ed.) pp. 67-85, Melbourne Univ. Press. (450)

North America

- Hayward, F. (1936) Soil changes associated with forest fires of the longleaf pine region of the South, Amer. Soil Survey Assoc. Bull. 176:1-19 (500)
- Robertson, W. B. Jr. (1955) A survey of the effects of fire in Everglades National Park, U.S. Dept. Interior, Nat. Park Serv (mimeo) (500)
- Sampson, A. W. (1944) Plant succession on burned chaparral lands in Northern California, Calif. Agric. Exper. Sta. Bull 685:1-144 (500)

Non-Regional

- Bagnouls, F. (1957) Les climats biologiques et leur classification, Bull. Soc. Geogr., No. 355, Mai-Juin, 1957, pp. 193-220. (600)
- Burgy, R. H. and V. H. Scott (1952) Some effects of fire and ash on the infiltration capacity of soils, Trans. Amer. Geophysical Union 33:405-416. (600)
- Burgy, R. H. (1953) Discussion of some effects of fire and ash on the infiltration capacity of soils, Trans. Amer. Geophysical Union, 34:293-295. (600)
- Byram, G. M. (1957) Some principles of combustion and their significance in forest fire behavior, Fire Control Notes 18(2):47-57. (600)

- Crosby, J. S. (1949) Vertical wind currents and fire behavior. Fire Control Notes 10(2):12-15. (600)
- Gilbert, J. M. (1963) Fire as a factor in the development of vegetation types, Austral Forestry, Vol. 27, pp.67-70. (600)
- Gisborne, H. T. (1948) Fundamentals of fire behavior, Fire Control Notes, 9(1):12-24. (600)
- Gisborne, Harry T. (1936) Measuring fire weather and forest inflammability, Washington, D.C., U.S. GPO, 59 pp. (600)
- Graham, H. E. (1957) Fire whirlwind formation as favored by topography and upper winds, Fire Control Notes 18:20-24. (600)
- Graham, H. E. (1960) Lightning probability forecast, Fire Control Notes 21(3):69-74. (600)
- Gray, Leslie G. (1936) Air temperature in relation to fire cost and damage, Jour. Forestry 34:779-785. (600)
- Green, S. W. (1935) Effect of annual grass fires on organic matter and other constituents of virgin longleaf pine soils, Jour. Agr. Research 50:809-822. (600)
- Hanson, H. C. (1939) Fire in land use and management, Amer. Midland Nat. 21:415-434. 1939. (600)
- Hayes, G. L. (1941) Influence of altitude and aspect on daily variations in factors of forest fire danger, Washington, D.C., GPO, 39 pp (600)
- Kivekas, J. (1939) Influence of shifting cultivation with burning upon some properties of the soil, Commun. Inst. Forest. Fenniae, 27: Helsinki. (600)
- Lee, H. C. (1941) Aerial photography, a method for fuel type mapping, Jour. For., 39:531-533. (600)
- Lindenmuth, A. W. Jr. and G. M. Byram (1948) Headfires are cooler near the ground than backfires, Fire Control Notes 9(4):8-9, 1948. (600)
- McArdle, R. E. (1935) A visibility meter for forest fire lookouts, Jour. Forestry 33:385-388. (600)
- McArthur, A. G. (1959) The effect of solar radiation on fire behavior, Institute of Foresters - Australian Newsletter 2:13. (600)
- Nobel, D. V. (1926) Relative humidity and the incidence of forest fires, Amer. Meteor. Soc. Bull. 7:74-77. (600)
- Proceedings Second Internat. Bioclimatological Congress, London, Sept. 1960, Pergamon Press, New York, 1962. (600)
- Reed, J. C. (1957) Vegetation studies for military purposes, Mil. Eng. 49(332):415-419. (600)

AC

- Reynards, J. J. (1962) The analysis of shifting cultivation areas. Int. Arch. Photogrammetry 14:171-176, Univ. Utrecht, Holland. (600)
- Scott, V. H. (1956) Relative infiltration rates of burned and unburned upland soils, Trans. Amer. Geophysical Union 37:67-69. (600)
- Scott, V. H. and R. H. Burgy (1956) Effects of heat and brush burning on the physical properties of certain upland soils that influence infiltration, Soil Sci. 82: 63-70. (600)
- Shallenberger, G. D. and E. M. Little (1940) Visibility through haze and smoke, and a visibility meter, Jour. Optical Soc. 30:168-176. (600)
- Sisam, J. B. W. (1947) The use of aerial survey in forestry and agriculture, Imperial Agricultural Bureau Joint Publ. No. 9:1-59. (600)
- Smith, W. C. and A. F. Ayres (1940) Lightning geography is key to protection, Electrical West 35:45-47. (600)
- World Meteorological Organization (1955-1956) World distribution of thunderstorm days, WMO/Omm No. 21. (600)

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13 ABSTRACT Fire in the tropics has a long history in which frequent wide-spread burning has profoundly altered physical and cultural environments. A vast and diverse literature pertaining to fire and its effects in tropical forests and grasslands has been evaluated, classified and presented in a selected bibliography. Emphasis is on the relation of fire to climate, natural vegetation, soils, cultural origins, technological level and way of life and other significant factors of the total environment. The incidence and frequency of occurrence of fire are examined in terms of the geographic distribution of passive and active environmental characteristics. The relationship of burning to climate and natural vegetation is shown on maps which represent a first attempt to depict the geographic distribution of fire in the tropics. Potential combustibility and the implications of fire to military operations are discussed.		

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